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Effect of phenol group antioxidant on performance & emission characteristic of diesel engine fuelled with diesel-jatropha biodiesel blend.

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Abstract— In conventional CI engine diesel is used as a fuel which provide better power, efficiency and BSFC but it increase the CO_2, CO, HC, SO_X and NOx emission. These gases affect the environment and human health. It causes global warming and greenhouse effect and responsible for acid rain too. Diesel is non-renewable energy resources and increase our dependency for importing fuel on other country.
Due to depletion of the fossil fuel and increasing hazardous effect on environment pollution an ecofriendly alternative is needed. It is observed that CI engine can be operated with blend of jatropha biodiesel with diesel blend without design modification. Using these blend in different proportion result shows that NOx emission increases and stability of fuel is also suffer. NOx emission and stability of biodiesel blends is tried to nullify by selecting phenol group antioxidant with different proportion.

Keywords— CI engine, phenol group antioxidant, jatropha biodiesel-diesel blends, NOx reduction, performance & emission characteristic

Abbreviations- FFA (Free fatty acid), PG (Propyl gallate), TBHQ (Tert-butyl-hydroquinone), PY (Pyrogallol)

Introduction

Jatropha oil cannot be used directly in CI engine due to its high viscosity, high molecular weight it causes the problem of filter chocking and injector chocking due to poor atomization and high molecular weight. For use of jatropha as a fuel reduction of its viscosity is needed and make it comparable to diesel fuel. This can be achieved by many ways like Pyrolysis, Micro emulsification, Dilution and transesterification. Among these, transesterification is the most commonly used commercial process for produce biodiesel.

The fatty acid triglycerides themselves are esters of fatty acids and the chemical splitting up of the heavy molecules, giving rise to simpler esters, is known as transesterification.

Biodiesel (fatty acid methyl ester) is produced by: FFA (free fatty acid) is catalysed by metallic Zn in esterification and triglycerides (TGs) transesterification catalysed by NaOH.

I Biodiesel Production

Jatropha oil is collected from the market and transesterification process is used to obtain jatropha biodiesel.1 litre of jatropha oil is taken in a flask and heated it up to 60 to 70 ˚C. Dark coloured high density glycerine is collected at the bottom of the bottle and low density biodiesel is collected above the glycerine which is separated by use of separating funnel and mixture of biodiesel is washed by using hot water.

Glycerol is highly soluble in water and biodiesel is not soluble in water which make a different layer of water mixing glycerol which is separated by funnel and pure biodiesel is obtain.

Biodiesel blend is obtain by mixing jatropha biodiesel and diesel fuel by volume/volume percentage .i.e.: B20 (20% jatropha biodiesel,80% diesel),B30 (30% jatropha biodiesel and 70% diesel),B40 (40% jatropha biodiesel,60% diesel).

TABLE 1 PROPERTIES OF JATROPHA BIODIESEL

Parameters	Unit	Value
Density @ 15 ˚C	kg/M3	892
Kinematic viscosity@40 ˚C	Centi poise	15.90
Kinematic viscosity@110 ˚C	Centi poise	10.16
Iodine value	-----	114
Acid value	MGKOH/GM	26
Flash point	˚C	132
Fire point	˚C	163
Gross calorific value	Kj/kg	42642

II . Blend preparation

B20 blend is prepared by mixing jatropha biodiesel and diesel fuel in a bottle by volume/volume percentage. In B20, 20% of biodiesel is mixed with 80% of diesel fuel. (E.g. in 1 litre of fuel 200 ml jatropha biodiesel and 800 ml diesel.).Same procedure is applied for preparation of B30 and B40 blend.

For addition of antioxidant different antioxidant is added to blend in different proportion by measuring its weight by electronic weight measurement instrument for regarding PPM calculating from its density and molecular weight.

For preparation of B20+200 PG, B20+500 PG, B20+1000 PG, 200 mg, 500 mg and 1000 mg PG is added into B20 respectively Which shows 200 ppm, 500 ppm and 1000 ppm proportion of antioxidant in fuel blend. Same procedure is applied for preparation of B30 and B40 blend.

III. Experimental setup

Fig. 1 Experimental setup

1. Single cylinder four stroke diesel engine
2. Eddy current dynamometer
3. Rotameter
4. Air box
5. Fuel tank
6. Burette
7. Fuel control valve
8. Load cell
9. Pressure sensor
10. Performance testing machine
11. AVL exhaust gas analyser
12. Exhaust probe

TABLE 2 ENGINE SPECIFICATION

Parameter	Specifications
Make	Kirloskar
Model	AV1
Method of cooling	Water cooled
Rated power	5 HP
Engine speed	1500 RPM
Bore × Stroke	87 mm × 110 mm
Volume	553 cc
Compression Ratio	Variable from 16.5 to 8.73

IV. Experimental Approach

For obtaining performance and emission characteristics of single cylinder diesel engine experimentation is carried out with b20 blend with 200 ppm of different phenol group antioxidants. B20+200PG, B20+200 PY and B20+200TBHQ is use as a fuel in CI engine and emission characteristics are obtained and by comparing this emission parameter best suitable antioxidant is find out for the jatropha biodiesel-diesel bend.by varying the proportion of this antioxidant with varying the blend proportion of fuel performance and emission parameter for different load condition is obtain.by comparing this parameter best proportion of blend with best proportion of antioxidant for better performance and emission is find out.

V. RESULT AND DISCUSSION

5.1 COMPARISON OF ANTIOXIDANTS

B20+200PG, B20+200 PY and B20+200TBHQ is use as a fuel in CI engine and emission characteristics are obtained and compare to decide the best antioxidant for jatropha biodiesel-diesel blend.

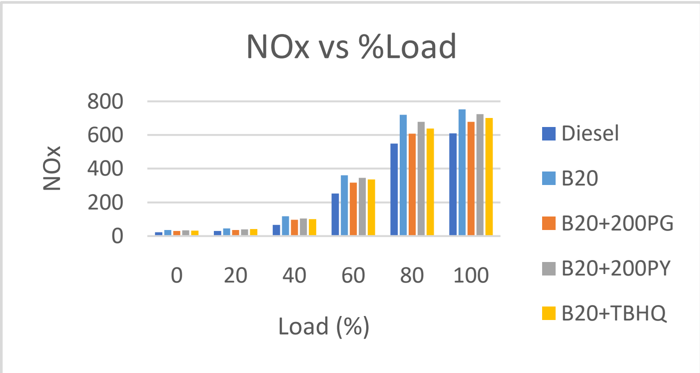

Figure 1 Variation in NOx with % Load

NO_x emission for B20 blend with the PG antioxidant is average 17.7%,11.2% & 7.8% less as compared to B20 without antioxidant,B20 blend with PY and B20 with TBHQ antioxidant respectively

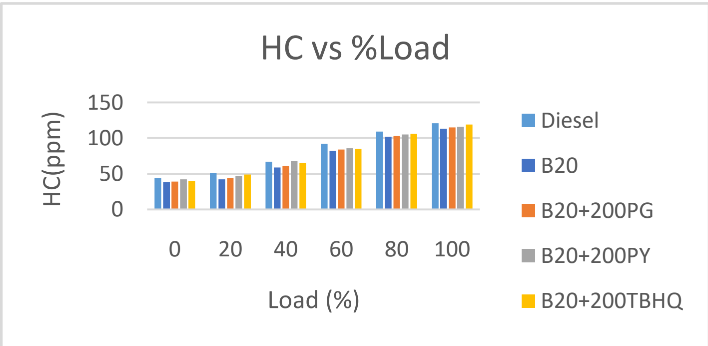

Figure 2 Variation in HC with % Load

HC emission for B20 blend with the PG antioxidant is average 2.6% higher compared to B20 without antioxidant and 5.3% & 7.6% less as compared to B20 blend with PY and B20 with TBHQ antioxidant respectively.
It is observed from the results that B20 blend with the PG as antioxidant gives better performance and emission characteristics as compared to B20 blend, B20 blend with TBHQ as antioxidant and B20 blend with PY as an antioxidant.

5.2 Engine Performance Data

Engine performance parameter like Brake power, brake thermal efficiency and brake specific fuel consumption are respectively discussed with diesel fuel, B20, B30 blend and with 200ppm, 500ppm and 1000ppm of PG antioxidant at different load conditions

5.2.1 Brake Power

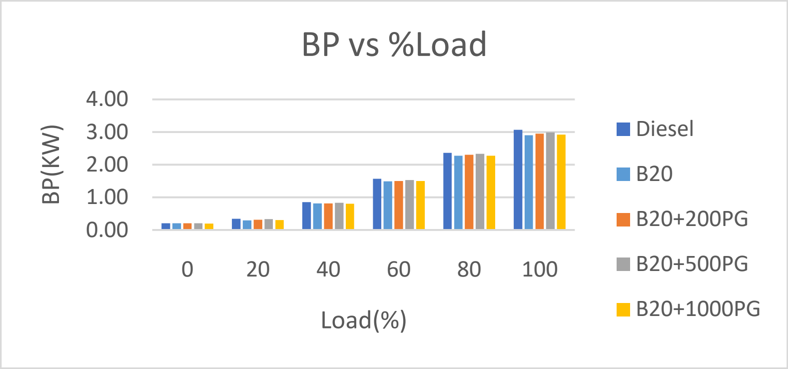

Figure 3 Variation in BP of B20 with % Load

Variation in brake power of B20 fuel with different proportion of PG antioxidant against load applied on engine is represented in figure 6.4.
Result shows that brake power is increase with increase in load applied on the engine for all the tasted fuel. Brake power is lower for all the B20 blends compare to diesel at all the loads. B20 blends decrease average brake power 5.75% compare to diesel. Addition of antioxidant increase brake power slightly for B20 fuel. Addition of 200,500 ppm of PG antioxidant increase average brake power 1.94%, 3.94% and 1.42% respectively compare to B20 fuel without antioxidant but further increase the proportion of antioxidant decrease the brake power.B20+1000 ppm PG blend produce 2.23% less power compare to B20+500 ppm PG fuel.

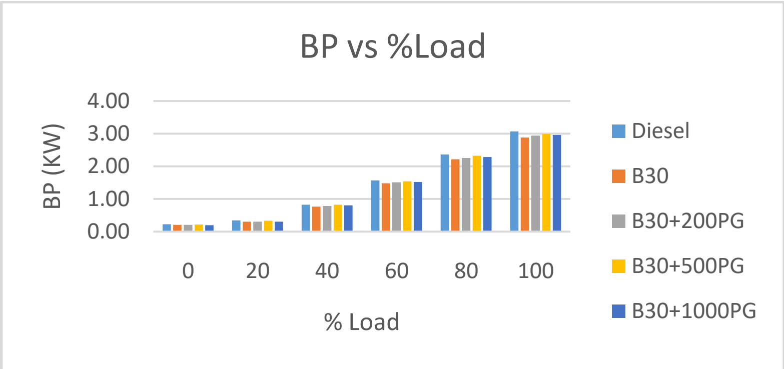

Figure 4 Variation in BP of B30 with %Load

Variation in brake power of B30 fuel with different proportion of PG antioxidant against load applied on engine is represented in figure 6.5.
Result shows that B30 blends decease average brake power 6.2% compare to diesel. Addition of antioxidant increase brake power slightly for B30 fuel. Addition of 200,500 and 1000 PPM of PG antioxidant increase average brake power 2.1%, 5.3% and 2.9% respectively compare to B30 fuel with antioxidant. here B30+1000 PPM produce 4.2 % less power compare to B30+500 PPM antioxidant.

Diesel-jatropha biodiesel blends B20,B30 produces lower Brake power than diesel because jatropha biodiesel have higher kinematic viscosity and higher density, resulting in less combustion. And higher power output of B20 and B30 jatropha biodiesel blend with antioxidant is mainly due to higher density and kinematic viscosity of the added-antioxidant fuels result in the injection of a larger mass of fuel to the engine for the same fuel volume.
Here antioxidant increase brake power for B30 blend is more than B20 blend of jatropha biodiesel.B30+1000 PPM PG antioxidant shows best result among all proportion of antioxidant.

5.2.3 Brake Thermal Efficiency

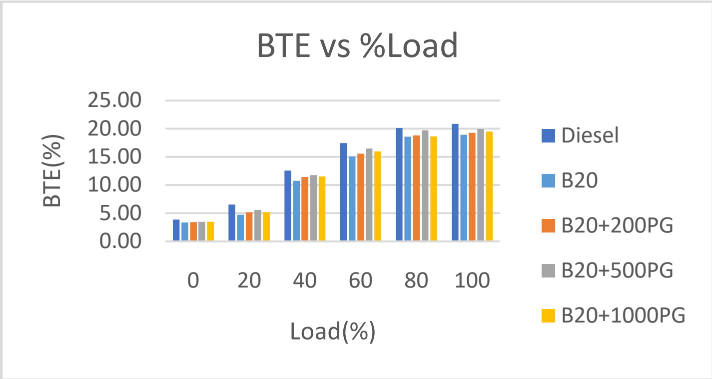

Figure 5 Variation in BTE of B20 with % Load

Variation in BTE of B20 fuel with different proportion of PG antioxidant against load applied on the CI engine is shown is fig 6.6. It shows that BTE is lower for all B20 fuel compare to diesel at all loads. BTE for B20 blend with antioxidant is higher compare to B20 blend without antioxidant. BTE is increase as proportion of PG antioxidant is increase in fuel up to 500 ppm but fuel with 1000 ppm antioxidant decrease BTE compare to 500 ppm antioxidant in fuel.
Average decrease in BTE for B20 blend is 13.3% compare to diesel fuel. addition of 200, 500 and 1000PPM antioxidant PG antioxidant in B20 increase BTE 4.2%,8.7% and 5.1% respectively compare to B20 blend without antioxidant. B20+1000 ppm blend shows 3.9 % less BTE compare to B20+500 ppm blend.

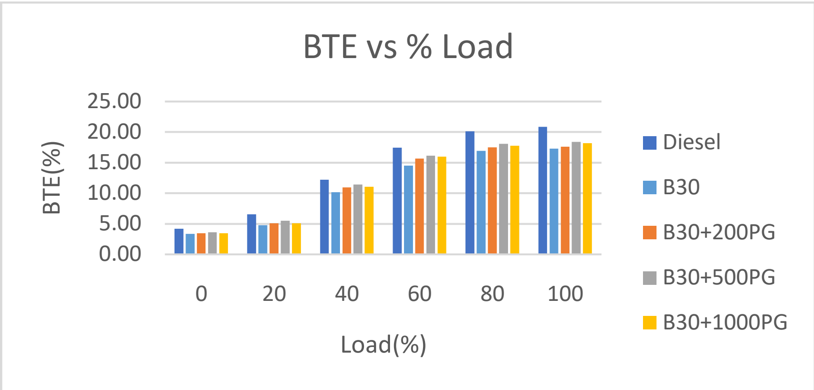

Figure 6 Variation in BTE of B30 with %Load

Variation in BTE of B30 fuel with different proportion of PG antioxidant against load applied on the CI engine is shown is fig 6.7. It shows that BTE is lower for all B30 fuel compare to diesel at all loads. BTE for B30 blend with antioxidant is higher compare to B30 blend without antioxidant. BTE is increase as proportion of PG antioxidant is increase in fuel up to 500 ppm but fuel with 1000 ppm antioxidant decrease BTE compare to 500 ppm antioxidant in fuel.
Average decrease in BTE for B30 blend is 13.6% compare to diesel fuel. Addition of 200, 500 and 1000PPM antioxidant PG antioxidant in B30 increase BTE 5.3%,10.6% and 6.7% respectively compare to B30 blend without antioxidant. B30+1000 ppm blend shows 5.7 % less BTE compare to B30+500 ppm blend.
The lower BTE of B20 and B30 is due to the combined effect of their lower heating value and higher viscosity. The addition of antioxidant PG into B20 &B30 increased the BTE, which is due to the higher power output and lower BSFC compared to B20 and B30. Here antioxidant shows better result with B30 blend compare to B20 blend.

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5.2.3 Brake Specific Fuel Consumption

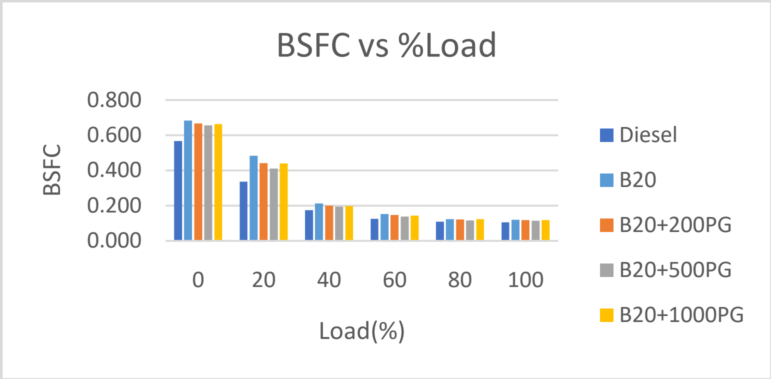

Figure 7 Variation in BSFC of B20 with % Load

Variation in BSFC of B20 fuel with different proportion of antioxidant against load applied on CI engine is shown in fig 6.8. It has been observed that BSFC was decreased with increase in load for all the tested fuels. BSFC for B20 increased compared to Diesel at all the loads. but addition of PG antioxidant decrease BSFC compare to B20 blend without antioxidant. And it decrease as proportion of antioxidant increase in blend up to 500 PPM. But with 1000 ppm antioxidant it increases.

Average increase in BSFC for B20 compared to Diesel was 14.4%. Addition of200, 500 and 1000ppm PG average BSFC decreases 3.9%, 7.8% and 4.7% compare to B20. B20+500 ppm blend shows 4.4 % less BSFC compare to B20+1000 ppm PG blend.

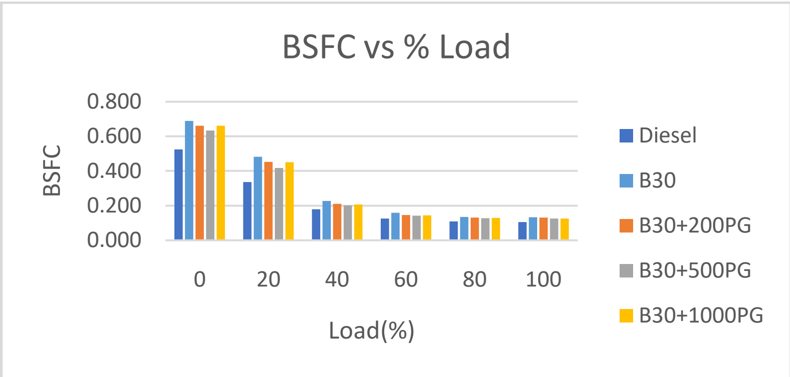

Figure 8 Variation in BSFC of B30 with % Load

Variation in BSFC of B30 fuel with different proportion of antioxidant against load applied on CI engine is shown in fig 6.9.

Average increase in BSFC for B30 blend compared to Diesel was 18.10 %. Addition of 200,500 and 1000ppm PG average BSFC decreases 5.01%, 9.17% and 6.23% compare to B30 blend without antioxidant.B30+500 ppm PG blend shows 8.2 % less BSFC compare to B30+1000 ppm PG blend.

The reason for higher BSFC for B20 and B30 compare to Diesel is, due to higher density, higher viscosity and lower calorific value of the B20 and B30 blend. The addition of antioxidants to B20 & B30 reduces BSFC. It was due to higher power output.

5.3 Engine Emission Characteristics

Variation of emission parameter like unburnt hydro carbon (HC), carbon monoxide (CO) and nitrogen oxide (NOx) of different diesel biodiesel blend with different proportion of PG antioxidant with different load conditions are discussed below.

5.3.1 Nitrogen Oxide (NOx)

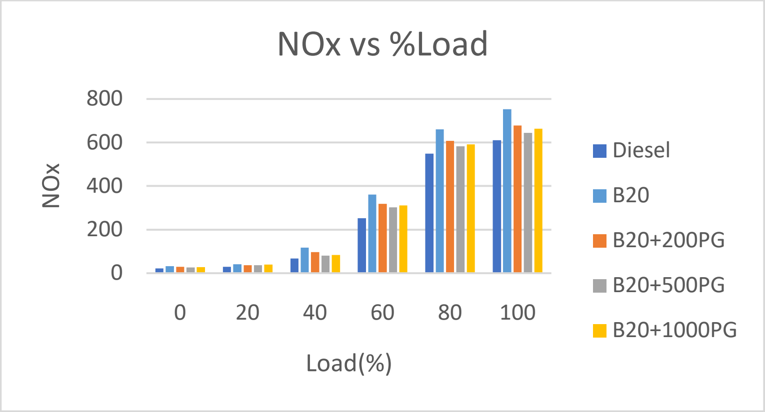

Figure 9 Variation in NOX of B20 with %Load

Variation in NOx emission of B20 fuel with different proportion of PG antioxidant against load applied on engine is shown in fig 6.10. It shows that B20 blend emits higher NOx compared to diesel at all the loads. To decrease higher emission of NOx PG is added into B20. As proportion of PG is increase in B20 up to 500ppm value of NOx emission decrease but for blend with 1000 ppm antioxidant is increase. Average increase in NOx emission for B20 compared to Diesel is 23.20%. Addition of 200,500 and 1000ppm PG in B20 decreases average NOx emission by 10.6%, 14.6% and 13.3% respectively compared to B20. NOx emission for B20+500 ppm PG blend 3.7% less compare to B20+1000 ppm PG blend

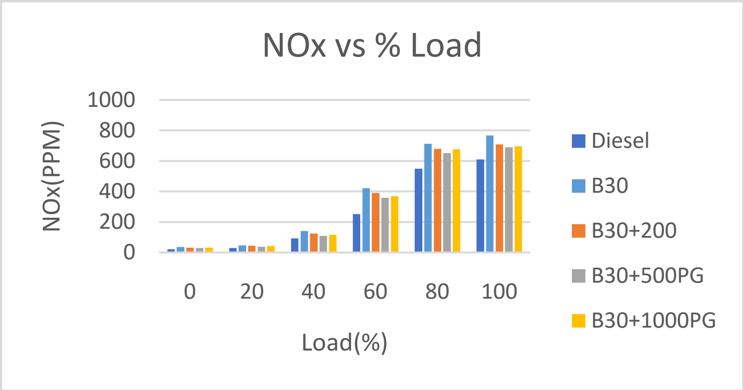

Figure 10 Variation in NOX of B30 with % Load

Variation in NOx emission of B30 fuel with different proportion of PG antioxidant against load applied on engine is shown in fig 6.11.

Average increase in NOx emission for B30 compared to Diesel is 26.70%. Addition of 200,500 and 1000ppm PG in B20 decreases average NOx emission by 8.2%, 15.5% and 11.4% respectively compared to B30. NOx emission for B30+500 ppm PG blend 6.8 % less compare to B30+1000 ppm PG blend.

NOx emission for B20 and B30 blend is higher compared to Diesel. During biodiesel combustion in diesel engine, the production rate of free radicals is higher. The reaction between molecular nitrogen and hydrocarbon radicals (CH, CH2, C2, C and CH2) is crucial in NOx formation. Addition of PG antioxidant decrease the amount of NOx emission in B20 and B30 blend compared to blends without antioxidant. This is mainly due to the phenolic hydroxyl groups present in PG interfere with the prompt NOx mechanism.

5.3.2 Hydro Carbon (HC)

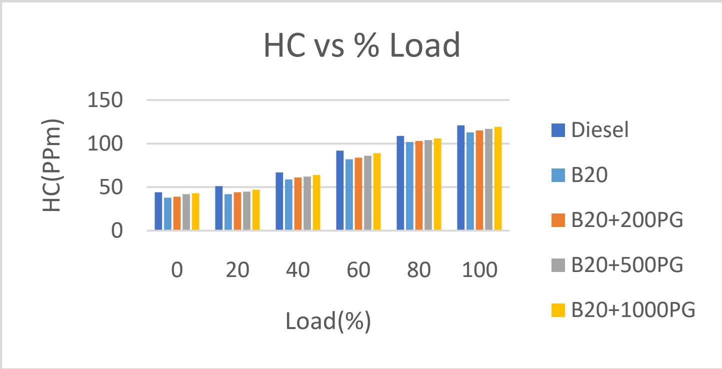

Figure 11 Variation in HC of B20 with % Load

Variation in HC emission of B20 fuel with different proportion of antioxidant against Load applied on CI engine is shown in fig 6.12. it shows that Compare to diesel B20 gives less HC emission at all the loads. As proportion of PG antioxidants in B20 increase the HC emission is also increase. Maximum HC emission was observed in B20 + 1000ppm PG compared to B20. Average decrease in HC emission for B20 compared to Diesel is 14.20%. Addition of 200,500 and 1000ppm of PG in B20 increase average 2.7%, 5.3% and 8.5% HC emission compared to B20 respectively. But it remains lower compare to diesel.

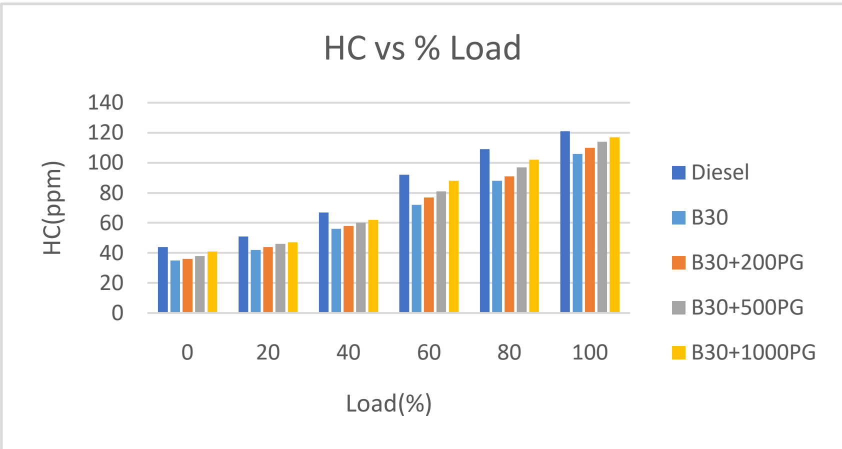

Figure 12 Variation in HC of B30 with % Load

Variation in HC emission of B20 fuel with different proportion of antioxidant against Load applied on CI engine is shown in fig 6.13. it shows that Compare to diesel B30 gives less HC emission at all the loads.

Average decrease in HC emission for B30 compared to Diesel is 16.30%. Addition of 200,500 and 1000ppm of PG in B30 increase average 2.9%, 5.6% and 9.2% HC emission compared to B20 respectively. But it remains lower compare to diesel.

Diesel-jatropha biodiesel blends B20 and B30 produce lesser HC emission compared to Diesel. This is due to the inbuilt oxygen content in its molecular structure this may be responsible for complete combustion and thus reducing the unburnt HC levels. Addition of PG antioxidant into blends increases HC emission. This increase is due to the reduction in oxidative free-radical formation

5.3.3 Carbon dioxide (CO_2)

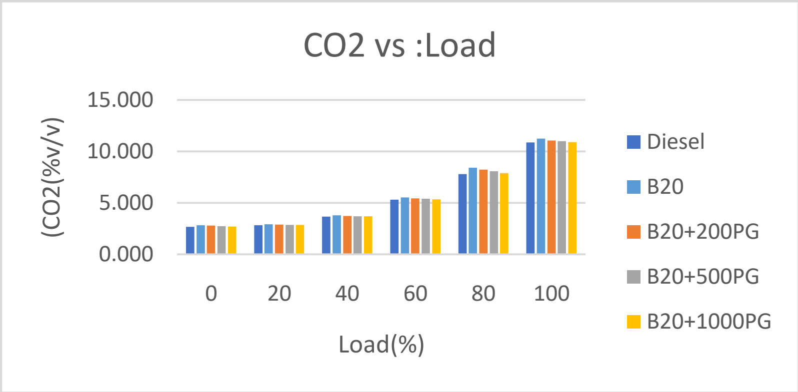

Figure 13 Variation in CO_2 of B20 with Load

Variation in CO_2 emission of B20 fuel with different proportion of PG antioxidant against load applied on CI engine is shown in fig 6.14. It shows that CO_2 emission is increases with the load applied on the engine. CO_2 for B20 blend is higher compare to diesel fuel. CO_2 for B20 blend decrease with the proportion of antioxidant increase in the fuel blend.
Average increase in CO_2 for B20 is 5.53% compare to diesel. And reduction in CO_2 emission for B20+200,B20+500 and B20+1000ppm PG is 1.6%,2.7% and 3.3% respectively.

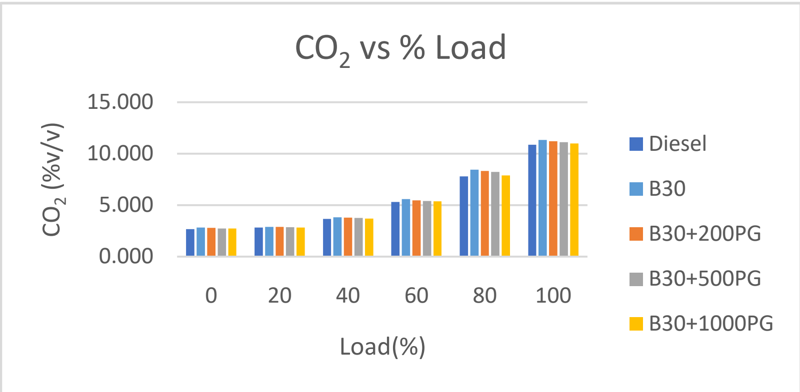

Figure 14 Variation in CO_2 of B20 with Load

Variation in CO_2 emission of B30 fuel with different proportion of PG antioxidant against load applied on CI engine is shown in fig 6.15. It shows that CO_2 emission is increases with the load applied on the engine. CO_2 for B30 blend is higher compare to diesel fuel.

Average increase in CO_2 for B30 is 5.3% compare to diesel. And reduction for CO_2 emission for B30+200, B30+500 and B30+1000ppm PG is 2.2%,2.75% and 3.1% respectively

In the blend B20 and B30 more amount of oxygen in the bio diesel accounts for better combustion inside the cylinder and hence reduced CO_2 emission. Addition of the antioxidant PG increases in CO_2 emission. This increase in the CO_2 emissions after adding antioxidant was due to the incomplete combustion related to amount of OH radicals (oxidation inhibitor) in the combustion reaction.

VI. CONCLUSION

- Oxidation process is retarted and stability of fuel is increased by adding antioxidants in fuel blend.
- Brake power for B20 blend is increase maximum with 500 ppm proportion of PG antioxidant 3.94% compare to B20 without antioxidant and in B30 blend it increase 5.3% compare to B30 without antioxidant. Here 500 ppm antioxidant increase BP for B30 blend is 4.2% more than B20 blend.
- BTE for B30 blend with 500 ppm proportion of PG antioxidant increase 10.6% compare to B30 without antioxidant.
- BSFC for B30 blend with 500 ppm proportion of PG antioxidant decrease 9.17% compare to B30 without antioxidant.
- In emission of NOx is decreases as increases the proportion of antioxidant in blend. For B20 blend max. Reduction for NOx emission is with 500 ppm PG antioxidant by 14.6% and for B30 15.5% compare to B20 and B30 blend without antioxidant respectively.
- HC emission is increase as proportion of antioxidant increases. Max increase in HC is for B20 blend is with 1000 ppm antioxidant by 5.5% and for B30 by 6.3% compare to B20 and B30 blend without antioxidant respectively.
- CO_2 emission is decreases with proportion of antioxidant increases in blend. Max reduction in CO_2 for B20 blend is with 1000 ppm PG antioxidant by 3.1% and for B30 by 3.3% compare to B20 and B30 blend without antioxidant respectively.

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