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Performance and Emission Characteristics Study of Diesel Engine using Diesel,Waste Cooking Oil and Ethanol Blends

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***Abstract:-* The present work focus on the use of waste cooking oil in diesel engine. A single cylinder four stroke diesel engine of Kirlosker make was run with waste cooking oil and its blends of B10, B20, B30, B40 and B50 to evaluate the performance with regard to brake power, brake thermal efficiency, brake specific fuel consumption and emissions such as NOX, UBHC, CO and CO2. For comparison, the same parameters were determined for engine operation with conventional diesel oil also. The effect of injector opening pressure (IOP) on the performance and emission characteristics of biodiesel blends of B10, B20, B30, B40 and B50 at three different IOP of 180, 200 and 220 bar were studied and the optimum biodiesel blend was determined which has resulted in better performance and emission characteristics with biodiesel blends as fuel. Also, investigations were carried out to study the effect of ethanol blend with B20 biodiesel blends on the performance and emission characteristics at optimum IOP of 220 bar for the best ethanol blend was determined.**

The result of this investigations revealed that the performance of engine with biodiesel and its blends has been improved at higher injection pressure. At an IOP of 220 bar, the performance and emission characteristics of biodiesel blends of B20 were better as compared to 200 bar, which is the normal IOP for diesel operation. The results of the studies on effect of blends at an optimised IOP of 220 bar has indicated that the B20 blend gave better performance and produced lower exhaust emissions from the engine.

**The biodiesel substantially reduces unburnt hydrocarbons, carbon monoxide and CO2 in exhaust gases, and slightly higher NOX than diesel fuel, but it was found that there is no significant difference between diesel and biodiesel in thus respect.
Also, the result of the studies on effect of ethanol on optimized biodiesel blend revealed that B20E10 blend gives better performance and lower exhaust emissions. The blend B20E10 gives better performance and lower emission of UBHC, CO and CO2 than the B20 blend at IOP of 220 bar.**

Keywords— Biodiesel, Ethanol, Injector opening pressure, Waste cooking oil.

I. INTRODUCTION

The diesel engine is widely used in power generation, transportation and agricultural machinery sectors; diesel engine is playing a more and more dominant role due to its superior thermal efficiency and fuel economy. At the same time, diesel engines are major contributors of various types of air pollutants such as carbon monoxide (CO), oxides of nitrogen (NOx), particulate matter (PM), and other harmful compounds and based on the depletion of fossil fuels and environmental considerations has lead to investigations on the renewable fuels such as ethanol, hydrogen, and biodiesel.

The feedstock coming from waste vegetable oils or commonly known as waste cooking oils is one of the alternative sources among other oils. Waste cooking oil is easy to collect from other industries such as domestic usage and restaurant and also cheaper than other oils. Hence, by using these oils as the raw material, we can reduce the cost in biodiesel production. Ethanol also commonly called ethyl alcohol, produced by the fermentation of sugars by yeasts. Ethanol is a volatile, flammable, colorless liquid with a slight chemical odor. It is used as an antiseptic, a solvent, a fuel and due to its low freezing point. The largest single use of ethanol is as an engine fuel and fuel additive. Blends of ethanol with diesel fuel are often referred to as "E-Diesel". Sometimes, ethanol-diesel blends are also called "oxygenated diesel", a term that is not particularly precise, as diesel blends containing methyl ester biodiesel or any other additive that includes oxygen can be also described as oxygenated diesel. The use of E-diesel can bring some reductions in diesel PM emissions, while contradictory reports exist on its effect on NO_x, CO, and HC emissions. Perhaps the biggest advantage of E-diesel is its partially

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renewable character, if renewable ethanol is used as the blending stock.

In order to achieve high degree of atomization for better penetration of fuel and complete combustion in shorter duration it need higher Injector opening pressure there by it significantly reduces the emission and increases the thermal efficiency and fuel economy.

II. FUEL BLENDS USED IN DIESEL ENGINE

Diesel

Diesel is a mixture of hydrocarbons obtained by distillation of crude oil. The important properties which are used to characterized diesel fuel include cetane number, fuel volatility, density, and viscosity. It is generally a liquid fuel used in diesel engines.

Biodiesel

Biodiesel is a clean burning alternative fuel produced from domestic, renewable resources. The fuel is a mixture of fatty acid alkyl esters made from vegetable oils, animal fats or recycled greases. The waste cooking oils used to produce biodiesel are the low cost and prevention of environment pollution ,When used as an additive, the resulting diesel fuel may be called B10, B20, B30 representing the percentage of the biodiesel that is blended with petroleum diesel.

III. TRANSESTERIFICATION

Transesterification is the process of reacting with alcohol in the presence of a catalyst to produce fatty acid esters and glycerol. Transesterification has been demonstrated as the simplest and most efficient route for biodiesel production in large quantities.

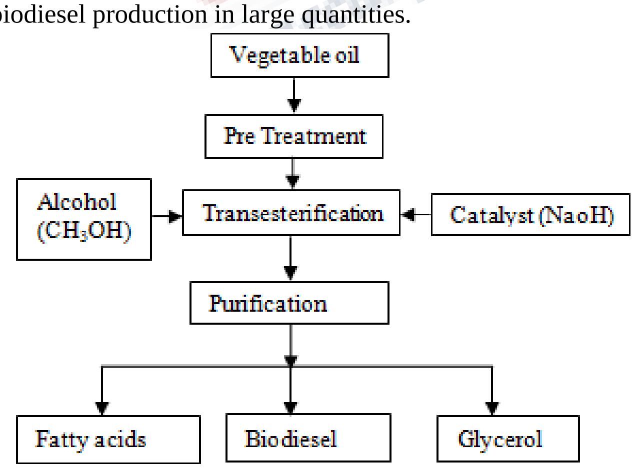

Fig. 1. Sequence of transesterification process

Ethanol

Ethanol is an alcohol most often chosen because of the ease of production. It can be obtained from various kinds of biomass such as maize, sugarcane, sugar beet, coffee husk, corn, cassava, and red seaweed etc., relatively low cost and low toxicity. The blending of ethanol to diesel affects fuel properties of the blends such as viscosity, lubricity, cetane number, energy content and mainly, volatility and stability. The ethanol blends with Diesel and Biodiesel are E5,E10,E15 for optimized injection pressure.

Objectives

- The overall objective of the research is to conduct Performance test on 4- stroke CI engine considering various important parameters.
- Preparation of biodiesel from waste cooking oil.
- Test the properties of diesel and biodiesel blends (B10, B20, B30, B40 and B50).
- Experimental test on four stroke diesel engine for various loads and blends (diesel and biodiesel) by varying injector opening pressure (180 bar, 200 bar, 220 bar).
- Comparison of experimental results to know the optimum biodiesel blend and its corresponding injector opening pressure.
- Test the properties of diesel biodiesel and ethanol blends (E5, E10 and E15).
- Experimental test on optimized blend with different ratios of ethanol (E5, E10, and E15) for optimized injection pressure.
- Comparison of experimental results to know the optimum blend.

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IV. METHODOLOGY

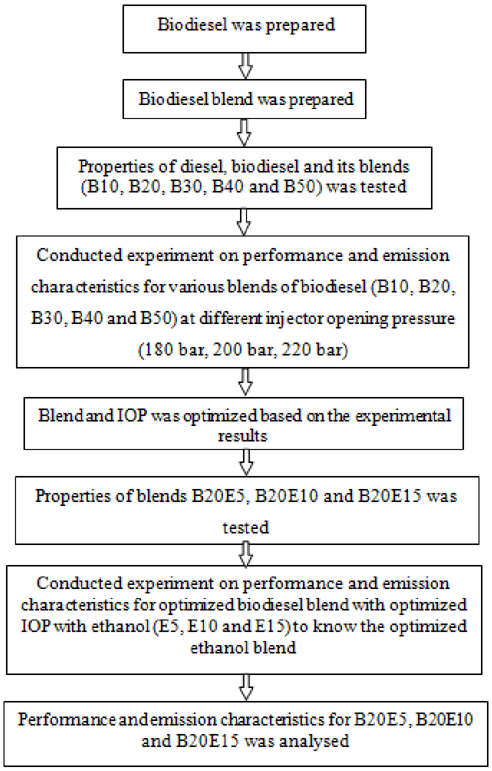

Fig. 2. Methodology experimental details

Table 1 Engine specification

Engine Parameters	Specification
Make	Kirlosker
Number of cylinders	One
Bore	80mm
Stroke	110mm
Cooling	Water
Fuel	Diesel
Speed	1400-1500RPM
Horse power	5hp
Starting	Manual
Lubrication	Forced

Table 2 Properties of Diesel, Bio diesel and Ethanol

Fuel	Kinematic Viscosity (m2/s)	Calorific Value (MJ/kg-k)	Flash Point (^oC)	Fire Point (^oC)
Diesel	0.00353	44.80	54	58
B10	0.00372	44.99	80	84
B20	0.00375	44.97	82	87
B30	0.00392	43.52	85	91
B40	0.00425	42.61	91	96
B50	0.00489	42.65	196	202
B100	0.00809	41.40	212	218
B20E5	0.00307	43.23	95	101
B20E10	0.00356	42.34	105	115
B20E15	0.00378	41.45	118	127

V. RESULTS AND DISCUSSION

The experimental setup consists of a single cylinder diesel engine, fuel measuring equipment, exhaust gas analyzer and thermocouples with temperature indicator. All the tests with different blend like B10, B20, B30, B40 and B50 will conduct for constant engine speed and with varying load on engine. Test was carried for 180bar, 200bar and 220bar fuel injection pressure at constant compression ratio 17.5. Initially test will conduct for diesel at different load and different injection pressure. After this initial test further experiment will conducted for B10 (10% biodiesel+90% diesel), B20 (20% biodiesel+80% diesel), B30 (30% biodiesel+70% diesel), B40 (40% biodiesel+60% diesel), B50 (50% biodiesel+50% diesel). Emission analysis will be carry for exhaust gas emission are unburnt hydrocarbon, carbon mono oxide, carbon di-oxide, oxygen, oxides of nitrogen. The performance parameters, brake thermal efficiency and brake specific fuel consumption will be measured. Exhaust gas temperature will be measure by using a 5gas analyzer and obtained data will tabulated in the Table 3 to 6.

Table 3 Performance and emission characteristics for B20 at injection pressure of 220 bar

Load (%)	BP (kW)	BSFC kg/kW-hr	BTE (%)	HC ppm	CO (%)	CO_2 (%)	NO_X ppm
0	0	0.52	0.03	24	0.03	1.2	202
25	1.25	0.4	19.52	26	0.02	2.2	572
50	2.36	0.28	26.59	30	0.01	3.2	1050
75	3.6	0.2	33.7	33	0.01	3.9	1405

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Table 4 Performance and emission characteristics for B20E5 at injection pressure of 220 bar

Load (%)	BP (kW)	BSFC kg/kW-hr	BTE (%)	HC ppm	CO (%)	CO_2 (%)	NO_X ppm
0	0	0.54	0	28	0.06	1.4	108
25	1.16	0.43	18.64	35	0.04	2.5	423
50	2.33	0.32	25.7	40	0.03	3.7	881
75	3.59	0.25	32.4	43	0.02	5.2	1263

Table 5 Performance and emission characteristics for B20E10 at injection pressure of 220 bar

Load (%)	BP (kW)	BSFC kg/kW-hr	BTE (%)	HC ppm	CO (%)	CO_2 (%)	NO_X ppm
0	0	0.51	0	22	0.04	0.9	175
25	1.18	0.41	19.62	25	0.03	2.1	475
50	2.37	0.29	27.2	28	0.02	2.9	892
75	3.61	0.18	34.22	32	0.02	3.8	1275

Table 6 Performance and emission characteristics for B20E15 at injection pressure of 220 bar

Load (%)	BP (kW)	BSFC kg/kW-hr	BTE (%)	HC ppm	CO (%)	CO_2 (%)	NO_X ppm
0	0	0.53	0	25	0.05	1.1	92
25	1.16	0.42	19.01	29	0.03	2.3	402
50	2.33	0.3	26.02	33	0.02	3.5	885
75	3.57	0.19	33.52	39	0.01	4.7	1192

Brake Thermal Efficiency (BTE)

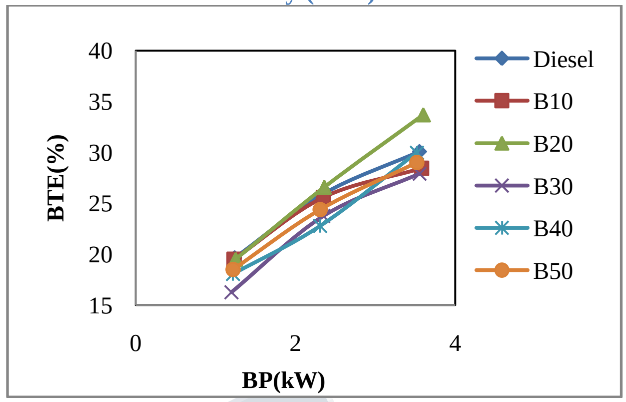

Fig. 1. Variation of brake thermal efficiency with brake power for diesel and WCO blends at 220 bar IOP

The variation of brake thermal efficiency with brake power for diesel and biodiesel blends at injection opening pressure of 220 bar was shown in Fig.1. Brake thermal efficiency has the tendency to increase with increase in engine load. Decrease of thermal efficiencies of biodiesel blends compared to diesel fuel in all loads was due to higher fuel consumption and lower heating value of biodiesel. B20 blend shows the higher thermal efficiency compare to other blends and it is 8.3% higher than the diesel fuel. And B30 blend shows the lower efficiency at full load condition.

Brake Specific Fuel Consumption

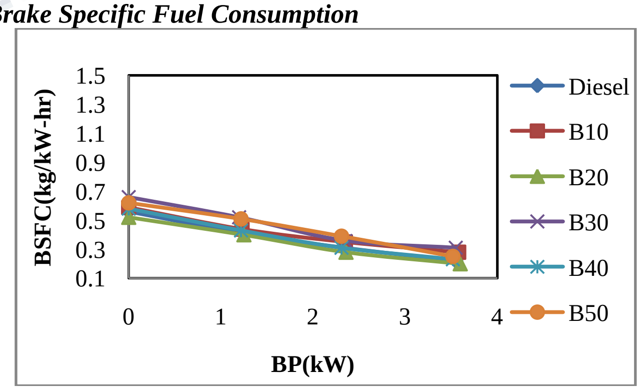

Fig. 2. Variation of brake specific fuel consumption with brake power for diesel and WCO blends at 220 bar IOP

Variation of specific fuel consumption with brake power for diesel and diesel-biodiesel blends as shown in Fig.2. at injector opening pressure of 220 bar. Specific fuel consumption decreased with the increase from lower loads to higher loads for all fuels due to increase of fuel consumption with load. B20 blend shows the lower brake

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specific fuel consumption compare to all other blends but it is 9.09% lower than the diesel at 75% load condition. B30 blend shows 29.03% higher brake specific fuel consumption compare to diesel at 75% load condition.

Emission Characteristics

Five major emissions produced by internal combustion engines are carbon monoxide (CO), hydrocarbons (HC), carbon dioxide (CO_2), oxides of nitrogen (NO_X).

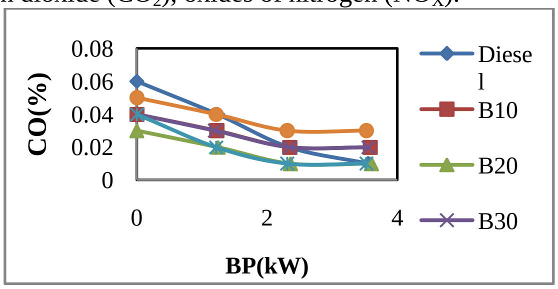

Fig. 3. Variation of CO emission with brake power for diesel and WCO blends at 220 bar IOP

Fig. 3. shows the carbon monoxide emissions of diesel and biodiesel blends with brake power at injector opening pressure of 220 bar. CO emissions decrease with the increase of load. From the Fig. 3. it can be observed that B20, B40 blend shows the lower emission of CO at 75% load condition and B50 blend shows the higher emission of CO. The CO

emission of blend B20 and diesel are same at 75% load condition.

Hydrocarbons

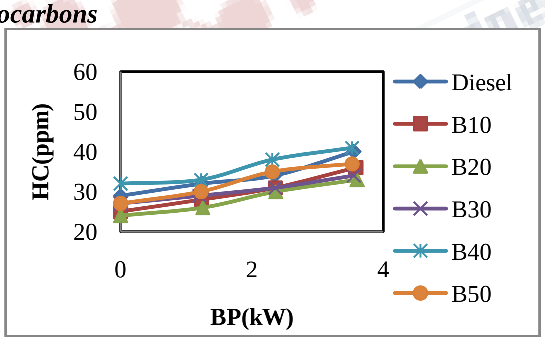

Fig. 4. Variation of HC emission with brake power for diesel and WCO blends at 220 bar IOP

Fig. 4. shows the variations of HC emissions for diesel and biodiesel blends with load at the IOP of 220 bar. It can be observed that B20 blend shows the lower emission of HC than the other blends and it shows 17.5% lower emission of HC than diesel at 75% load condition.

Carbon Dioxide

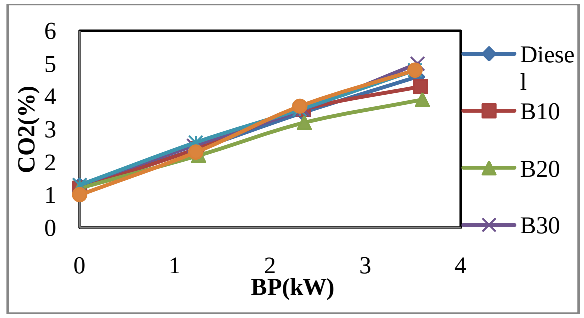

Fig. 5. Variation of CO_2 emission with brake power for diesel and WCO blends at 220 bar IOP

The Fig. 5. shows the variation of CO_2 emission for diesel and biodiesel blends with brake power at the IOP of 220 bar. It can be observed that CO_2 emission is lower in B20 blend than the other blends and it is higher in B50 blend. CO_2 emission in blend B20 is 15.21% lower than the diesel.

Oxides of Nitrogen

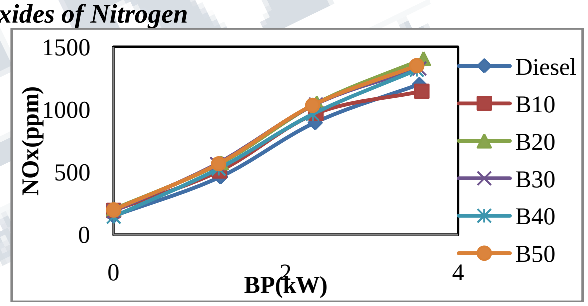

Fig. 6. Variation of NO_X emission with brake power for diesel and WCO blends at 220 bar IOP

Variations of NO_X emissions for diesel and biodiesel blends with brake power at IOP of 220 bar are shown in Fig. 6. it can be observed that NO_X emission is lower in B10 blend and it is higher B20 blend. The B20 blend shows 14.59% of higher emission of NO_X than diesel at 75% load condition.

Optimization of Blend

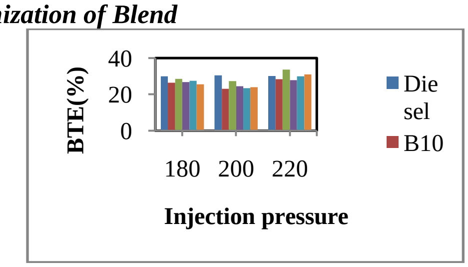

Fig. 7. Variation of brake thermal efficiency with injection opening pressure at full load condition

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Fig. 7. shows the variation of brake thermal efficiency for diesel, B10, B20, B30, B40 and B50 at injection opening pressure 180 bar, 200 bar, 220 bar at full load condition. Brake thermal efficiency has the tendency to increase with increase in engine load. At all the injection opening pressure B20 blend has the higher brake thermal efficiency than the other blends. B20 blend has 8.3% higher brake thermal efficiency than diesel at 220 bar injection opening pressure. Further test will be conducted for optimized blend B20 with the variation of ethanol percentage like E5, E10, and E15 at 220 bar injection opening pressure.

Variation of Ethanol Percentage to Optimized Blend

Brake Thermal Efficiency

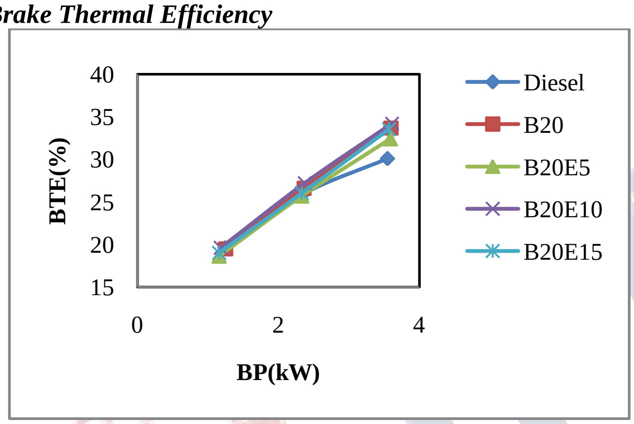

Fig. 8. Variation of brake thermal efficiency with brake power for diesel, WCO and ethanol blends at 220 bar IOP

The Fig. 8. shows the variation of brake thermal efficiency with brake power and it shows that brake thermal efficiency increases with increasing load. Brake thermal efficiency has the tendency to increase with increase in engine load. This was due to the reduction in heat loss and increase in power developed with increase in engine load. From the Fig. 8. it can be observed that B20E10 shows the higher thermal efficiency than all other blends and it shows 9.70% higher thermal efficiency than diesel at 75% load condition.

Brake Specific Fuel Consumption

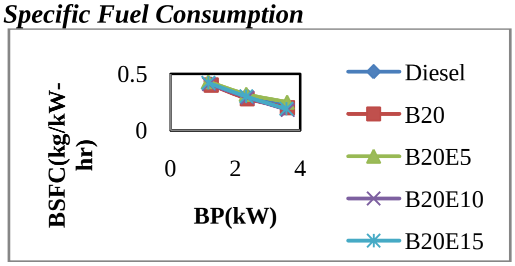

Fig. 9. Variation of brake specific fuel consumption with Brake Power for diesel, WCO and ethanol blends at 220 bar IOP

The Fig. 9. shows the variation brake specific fuel consumption with brake power. Specific fuel consumption decreased with the increase from lower loads to higher loads for all fuels due to increase of fuel consumption with load. It can be observed that brake specific fuel consumption is lower for B20E10 blend than the other blends it has the lower brake specific fuel consumption of 18.18% lower than diesel at 75% load condition.

Hydrocarbons

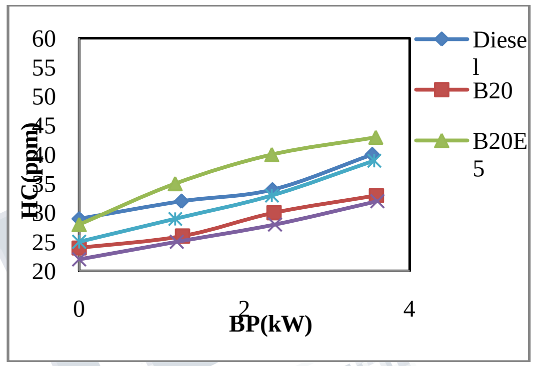

Fig. 10. Variation of HC emission with brake power for diesel, WCO and ethanol blends at 220 bar IOP

The Fig. 10. shows the variation HC emission with brake power, HC emissions increased as the engine load increased due to the increase of fuel consumption at higher loads. Cetane number of biodiesel resulted decrease in HC emission due to shorter ignition delay. Lower HC emissions of biodiesel blends were due to the presence of fuel bound oxygen and warmed up conditions. It can be observed that HC emission is lower for B20E10 blend than the other blends it has 20% lower HC emission than diesel at 75% load condition.

Carbon Monoxide

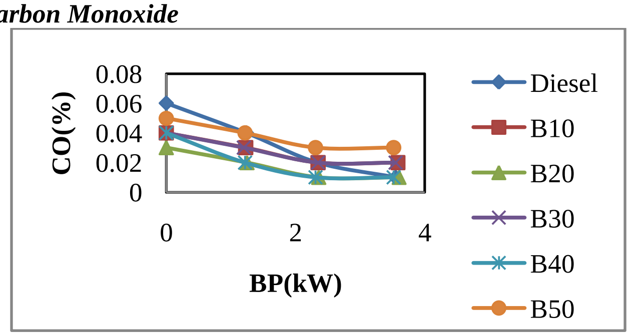

Fig. 11. Variation of CO emission with brake power for diesel and WCO blends at 220 bar IOP

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Fig. 11. shows the variation of CO emission with brake power, the emission of CO decreases with load change from lower value to higher value due to decrease of air-fuel ratio at higher loads. The higher combustion temperature at lower engine loads contributed to the general decreasing trend of CO emission. The decrease in carbon monoxide emission for biodiesel blends was due to more oxygen molecule present in the fuel, improved atomization and better vaporization of biodiesel resulting in complete combustion as compared to diesel fuel. The higher amount of oxygen in biodiesel will promote further oxidation of CO emission. B20 blend shows the lower emission of CO and B20E5 blend shows the higher emission of CO. The blend B20 and diesel shows similar emission of CO at 75% load condition.

Carbon Dioxide

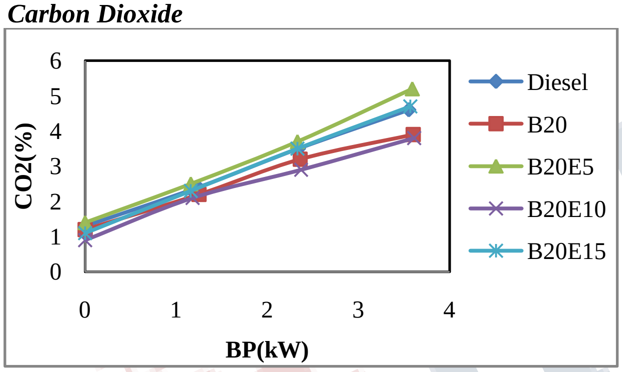

Fig. 12. Variation of CO_2 emission with brake power for diesel, WCO and ethanol blends at 220 bar IOP

The Fig.12. shows the variation of CO_2 with brake power, emission of CO_2 is increased with increasing load, Lower percentages of CO_2 emissions were produced when diesel engine fueled with biodiesel and ethanol compared to diesel fuel. This was due to the lower carbon to hydrogen ratio in biodiesel compared to diesel fuel. The blend B20E5 shows the higher emission of CO_2 and the blend B20E10 shows the lower percent emission of CO_2. B20E10 blend shows 17.39% lower emission than diesel and 2.5% lower than B20 blend at 75% load condition.

Oxides Of Nitrogen

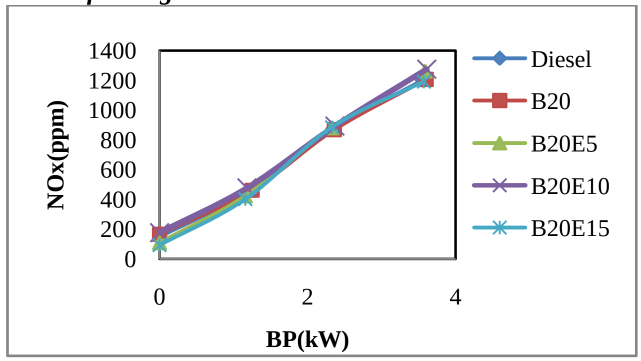

Fig. 13. Variation of NO_X emission with brake power for diesel, WCO and ethanol blends at 220 bar IOP

The Fig. 13. shows that emission of NO_X increases with increase of load, NO_x emission is depend upon combustion temperature, oxygen concentration and reaction time. NO_x emission is increases due the presence of oxygen in blend. As the blending increase NO_x emission increases emission of NO_x is almost same for the blends B20 and B20E5. The blend B20E10 shows the higher emission of NO_x compare to all other blends. B20E10 blend shows 5.88% higher NO_x emission than diesel at 75% load condition.

VI. CONCLUSION

The performance and emission characteristics of diesel, waste cooking oil biodiesel, and its blend and diesel-biodiesel-ethanol blends were investigated on a single cylinder diesel engine. The conclusions of this work are as follows

- The maximum thermal efficiency (33.7%) was observed with the blend B20 at 220 bar injector opening pressure. and it is 8.3% higher than the diesel.
- The brake specific fuel consumption increased with the increased percentage of diesel biodiesel blends. B20 blend shows 9.09% lower brake specific fuel consumption than diesel at 220 bar injection opening pressure.
- HC emissions were found to significantly increases with load, B20 blend gives 17.5% lower emission of HC at injection opening pressure of 220 bar.
- CO emission decreases with increase of load. B20 gives lower emission compare to diesel.
- B20 blend gives 15.21% lower emission of CO_2 than diesel at 220 bar injection opening pressure.
- NO_X emission is slightly higher than the diesel fuel.

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- Thus the blend B20 can be concluded as a optimized blend
- When blend B20 was investigated with different ratios of ethanol (E5, E10 and E15) at optimized injector opening pressure 220 bar the following conclusions can be obtained
- The brake thermal efficiency is higher in B20E10 blend, brake thermal efficiency of B20E10 blend is 9.70% higher than the diesel.
- The specific fuel consumption of B20E10 blend is 18.18% lower than the diesel.
- The HC emission in B20E10 blend is lower than the B20 blend and diesel and the emission is 20% lower than diesel.
- The blend B20E10 gives lower emission of CO_2 than the other blends and it is 17.5% lower than diesel.
- The blend B20E10 shows slightly higher emission of NO_x compare to all other blends.

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