International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-5, March 2020

Emission and Combustion Characteristics of Biodiesel with Dee Additive and Thermal Barrier Coated Piston

Sanjay Singh, M Prabhahar

Abstract: ***Continuous emissions of green house gases like carbon dioxide by industries and automobiles in atmosphere is increasing day by day and if not checked and regulated may bring disasters to human life. The existence and continuation of human life will be at risk. All technocrats, engineers and environmentalists have to work together for designing engineering systems and especially automobiles for combustion of fuels especially biodiesel which reduces emission of green house gases. Also there is a requirement of biodiesels to be renewable and obtained from biomass.***

The methyl ester produced from algae is used as a source of energy and is tested for its suitability in a variable compression ratio diesel engine (VCR). Blend B20 is added with 10% diethyl ether and tested for its combustion and emission characteristics with 200 micron zirconia coated piston. Improvement in performance is observed in comparison to the characteristics obtained with only coated piston and without additive.

Key words — Algae, Green House Gas, Thermal barrier, Zirconia coating.

I. INTRODUCTION

Environmental degradation and depleted layers of fossil fuels have made technocrats worried as the life will be in a halt like situation due to sudden stoppage of vehicles and industries. If the consumption of fossil fuels is continued at the same rate what we are doing today, our future generations will suffer very badly and fossil fuels on earth may become historical facts for them. Simultaneously use of fossil fuels indiscriminately have resulted a great amount of emission of green house gases like carbon dioxide thereby damaging the earth atmosphere and destruction of protective envelope meant for saving land and water from unnecessary heating and harmful rays of the sun caused rise in earth's temperature. If this rise in temperature is not stopped immediately, melting of glaciers will take place at a faster rate and flood like situation will arise thereby land portion of earth will become submerged.

The necessity to preserve fossil fuels and simultaneously discover another alternative fuel especially renewable source of energy is the prime area of research today. No doubt the power and mechanical characteristics obtained with fossil fuel has not been obtained with any other alternative fuel including biodiesel.

Revised Manuscript Received on March 30, 2020.
* Correspondence Author
Mr. Sanjay Singh*, Vinayaka Mission's Kirupananda Variyar Engineering College, Salem, Tamil Nadu, India.
Dr. M. Prabhahar, Professor in Aarupadai Veedu Institute of Technology, Chennai, Tamil Nadu, India

But biodiesel has been coming out as the strong competent and its characteristics can be improved further by using some advanced techniques like addition of additives, varying injection pressure etc.

The biodiesel or methyl ester from biomass like chlorella microalgae is obtained through transesterificaion process by using ethyl or methyl alcohol as catalyst. These algae are available in abundance and can be grown easily under normal as well as controlled climatic conditions. The microalgae is edible and even used in medicines. The methyl ester is separated and left out glycerol is utilized in cosmetics industries.

The blend B20 of biodiesel obtained using chlorella microalgae is added with 10% diethyl ether (DEE) as additive and tested for its combustion and emission characteristics in a variable compression ratio engine fitted with 200 micron stabilized zirconia coated piston. The thermal barrier coating of piston provides high heat retention thereby loss of heat is reduced from the engine. The technique is used to provide complete combustion and conversion of large amount of heat into brake power and useful work.

In this paper, the test results obtained by using biodiesel plus 10% DEE with zirconia coated piston is compared with the characteristics obtained with blend B20 without DEE but with coated piston only. A comparative analysis is done in order to find improvement in performance and emission characteristics by using DEE and zirconia coated piston and the same is compared with the corresponding characteristics of pure diesel with normal piston made of cast aluminium alloy as used in most automobiles. It facilitates use of engine with biodiesel as it is with biodiesel without much considerable modifications.

II. ZIRCONIA COATING ON PISTON CROWN

Zirconium is a transition metal. Its colour is silver gray. The atomic number is 40 and its melting point is 1855 ^{0}C. The metal is highly malleable and ductile but is not as strong as titanium. Zirconium oxide or zirconia is a white crystalline material. A saturated coating of 200 micron is done on piston crown. The metal has high corrosion resistance properties and high thermal expansion properties.

III. DIETHYL ETHER (DEE)

Diethyl ether is an organic compound. The chemical formula is $C_2H_5OC_2H_5$. It is a highly volatile, flammable and colorless liquid. It is also called as ethyl ether and its IUPAC name is ethoxyethane. It is having a distinctive odor.

Excess inhalation of DEE may cause headache, nausea, vomiting and loss of consciousness. High exposure of diethyl ether should be avoided as it may cause damage to the kidney. It undergoes combustion reaction with formation of carbon dioxide and water.

Table 1: Chemical Properties of Diethyl Ether

1.	Density	713 kg/m³
2.	Molecular Weight	74.12 g/mol
3.	Melting Point	-116.3 °C
4.	Boiling Point	34.6 °C

IV. EXPERIMENTAL SET UP

Single cylinder four stroke. Water Cooled, Constant Speed Diesel Engine is used for conducting experiments.

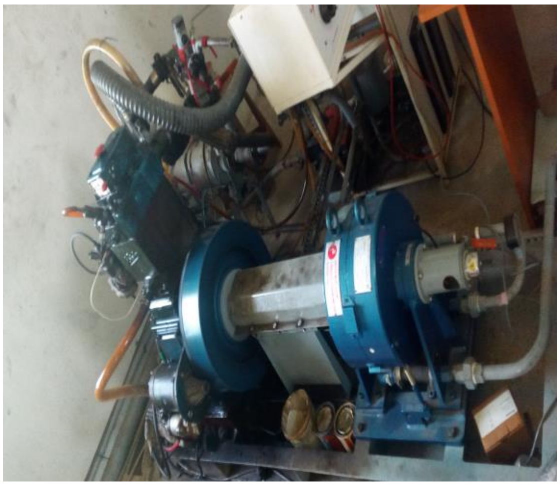

Figure 1: VCR Engine.

Table 2: Engine Parameters.

Sl. No.	Description	Values
1.	Connecting Rod - Length	234.00 mm
2.	Volume - Swept	661.45 cm^3
3.	Cylinder - Diameter	87.50 mm
4.	Stroke - Length	110.00 mm
5.	Power	5.20 kW @ 1500 RPM
6.	Compression Ratio	17.50

Figure 2: Normal Cast Aluminium Alloy Piston

Figure 3: Zirconia Coated Piston – Crown Only.

V. PROPERTIES OF BIODIESEL AND PURE DIESEL

Table 3: Chemical properties of Biodiesel and Pure Diesel.

Sl. No.	Description	Standard Lab Conditions - 40⁰C - Algae Biodiesel	ASTM Standards - Diesel
1.	Nature of Sample	B100	D100
2.	Kinematic Viscosity – cSt	4.07	2 - 4.5
3.	Density -Kg/m^3	896	820 – 860
4.	Fire Point - ⁰C	119	210
5.	Flash Point - ⁰C	108	> 35
6.	Calorific Value - kj/kg	39321	46000

VI. EXPERIMENTS AND RESULTS - COMBUSTION CHARACTERISTICS

A. Brake Power

Power produced by the engine and is converted into useful work is called brake power.

Table 4: BP in kW.

Engine Load in %	B20 CP	B20 CP + DEE	Diesel NP
0	0.03	0.04	0.02
25	1.32	1.35	1.32
50	2.57	2.58	2.58
75	3.76	3.83	3.76
100	4.94	4.96	4.96

Retrieval Number: E2792039520/2020©BEIESP
DOI: 10.35940/ijitee.E2792.039520
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

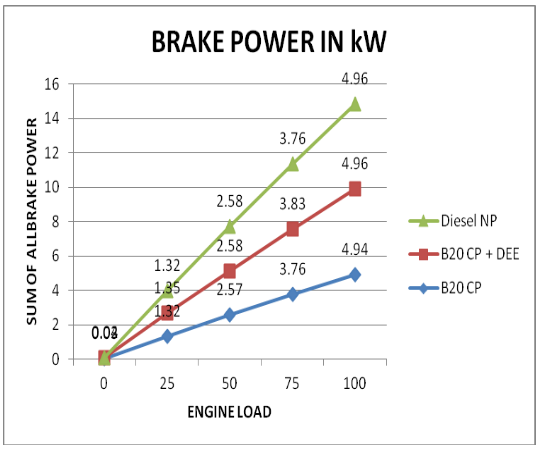

Figure 4: Engine Load - Brake Power in kW.

Result:

Table: 5 – BP - Variations.

B20 CP vs D100 NP (in %)	B20 CP + DEE vs D100 NP (in %)
50.00	100.00
0.00	2.27
-0.39	0.00
0.00	1.86
-0.40	0.00
+ Increase, - Decrease **(in %)**	

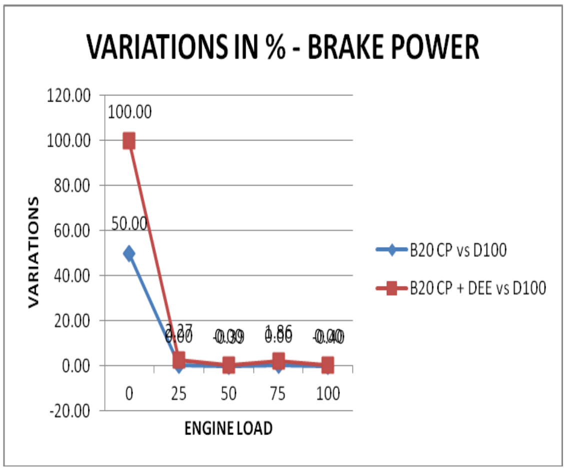

Figure 5: Engine Load in % vs Brake Power in kW.

100% increase in brake power is found with B20 CP + DEE at 0% engine load. Overall in some cases power converted to useful work is even more than B20 CP. The reason is high volatility achieved by using DEE as additive and thereby complete combustion.

B. Brake Mean Effective Pressure (BMEP)

Fuel is combusted in the cylinder and due to combustion high pressure is generated in the cylinder.

Table 6: BMEP in bar.

Engine Load in %	B20 CP	B20 CP + DEE	Diesel NP
0	0.03	0.04	0.03
25	1.58	1.6	1.59
50	3.14	3.16	3.14
75	4.69	4.72	4.69
100	6.27	6.28	6.27

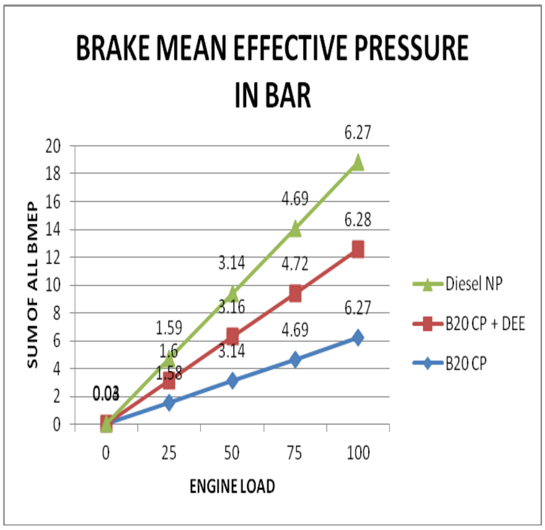

Figure 6: Engine Load - BMEP.

Result:

Table: 7 – Variations - BMEP

B20 CP vs D100 NP (in %)	B20 CP + DEE vs D100 NP (in %)
0.00	33.33
-0.63	0.63
0.00	0.64
0.00	0.64
0.00	0.16
+ Increase, - Decrease	

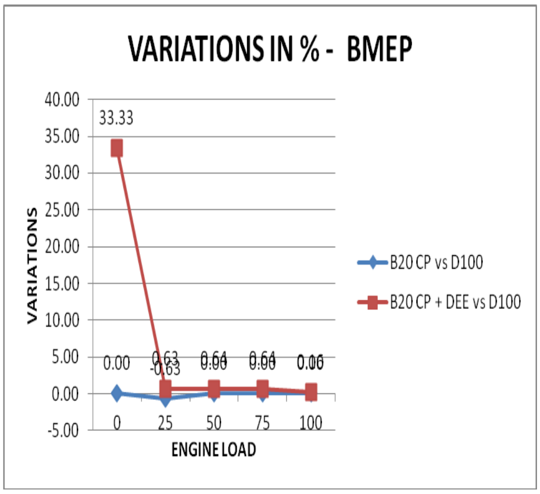

Figure 7: Engine Load - BMEP.

With B20 + DEE + CP, 33% increase in BMEP is found at 0% engine load and marginal increase is observed at all other loads. This is because of high atomization and better combustion.

C. Brake Thermal Efficiency (BTE)

Net heat utilized for producing useful work is related to brake thermal efficiency.

Table 8: BTE in %.

Engine Load in %	B20 CP	B20 CP + DEE	Diesel NP
0	0.63	0.64	0.65
25	18.67	18.7	18.73
50	25.7	26.57	27.39
75	29.03	29.9	30.49
100	32.17	32.38	32.46

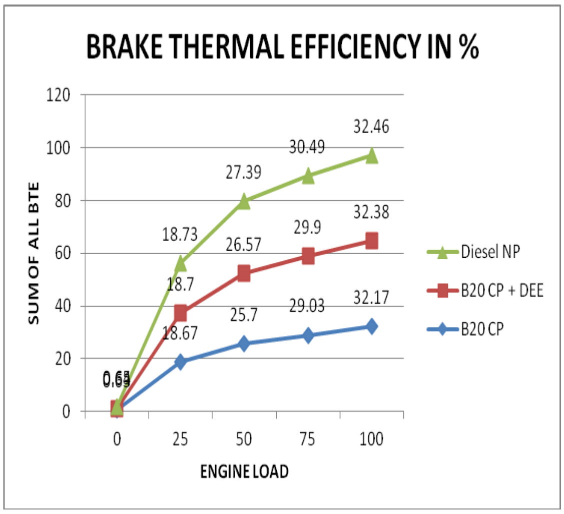

Figure 8: Engine Load - BTE

Result:

Table: 9 – Variations – BTE

B20 CP vs D100 NP (in %)	B20 CP + DEE vs D100 NP (in %)
-3.08	-1.54
-0.32	-0.16
-6.17	-2.99
-4.79	-1.94
-0.89	-0.25
+ Increase, - Decrease	

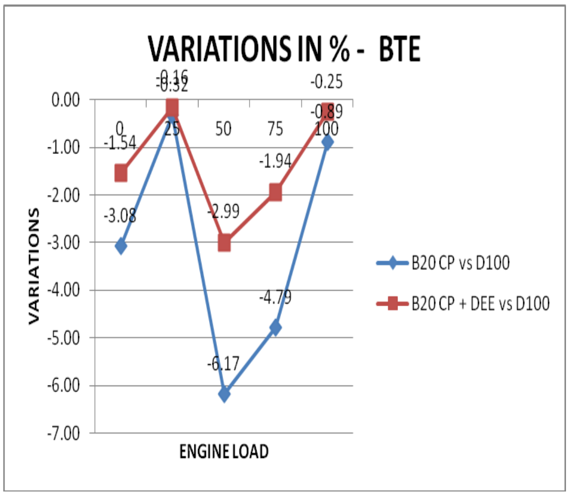

Figure 9: Engine Load – BTE.

Marginal increase is observed in brake thermal efficiency in case of B20 + DEE + CP in comparison to B20 + CP.

D. Specific Fuel Consumption (SFC)

SFC indicates power produced by the engine with respect to fuel consumption. A low value is the requirement.

Table 10: SFC in kg/kWh.

Engine Load in %	B20 CP	B20 CP + DEE	Diesel NP
0	13.7	20.73	14.68
25	0.46	0.43	0.45
50	0.33	0.3	0.31
75	0.3	0.3	0.28
100	0.27	0.26	0.26

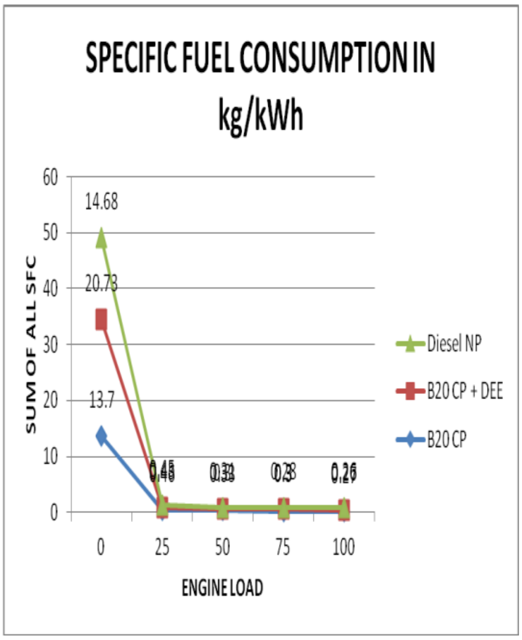

Figure 10: Engine Load – SFC

Result:

Table: 11 – Variations - SFC.

B20 CP vs D100 NP (in %)	B20 CP + DEE vs D100 NP (in %)
-6.68	41.21
2.22	-4.44
6.45	-3.23
7.14	7.14
3.85	0.00
+ Increase, - Decrease	

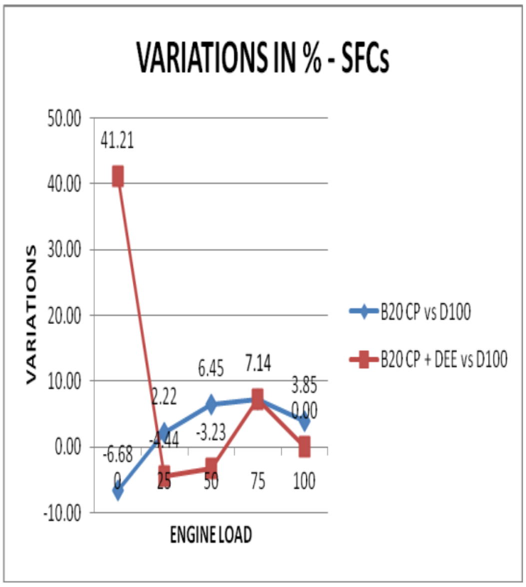

Figure 11: Engine Load - SFC in kg/kWh.

41.21% increase in SFC is found at 0% engine load with B20+CP+DEE. At 25 % and 50% engine load, the SFC has reduced by 4.44% and 3.23% for B20+CP+DEE with respect to pure diesel with normal piston.

E. Mechanical Efficiency

Mechanical component of the engine working together for conversion of chemical energy of fuel to mechanical work is called mechanical efficiency of the engine.

Table 12: ME in %.

Engine Load in %	B20 CP	B20 CP + DEE	Diesel NP
0	0.94	0.97	1.09
25	37.18	38.06	35.52
50	55.52	57.6	52.49
75	66.88	68.6	64.41
100	75.67	76.6	71.78

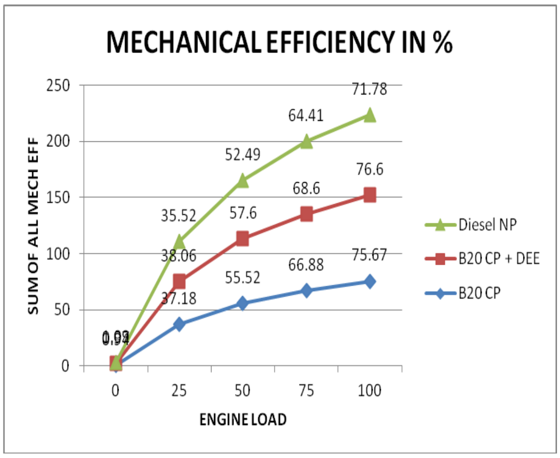

Figure 12: Engine Load - Mechanical Efficiency.

Result:

Table: 13 – Variations - Mechanical Efficiency.

B20 CP vs D100 NP (in %)	B20 CP + DEE vs D100 NP (in %)
-13.76	-11.01
4.67	7.15
5.77	9.74
3.83	6.51
5.42	6.71
+ Increase, - Decrease	

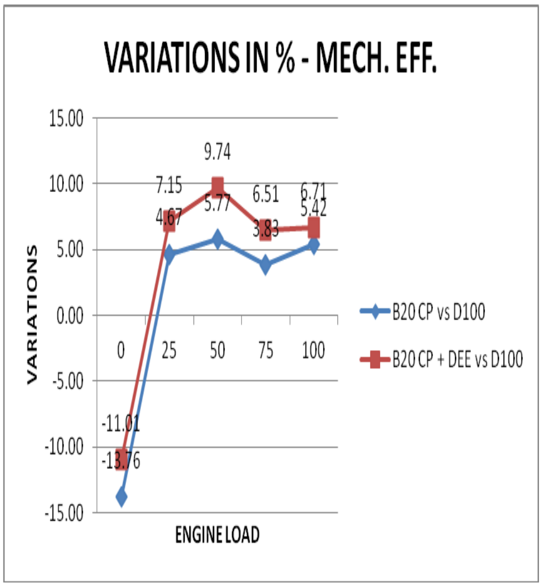

Figure 13: Engine Load - Mechanical Efficiency in %.

For B20+CP+DEE, except at 0% engine load, increase in mechanical efficiency is found. At 0% engine load, 11.01% decrease in efficiency is observed and that may be due to improper combustion at initial stage.

F. Engine Torque

Power used to produce turning moment in the engine is called engine torque.

Table 14: Engine Torque in Nm.

Engine Load in %	B20 CP	B20 CP + DEE	Diesel NP
0	0.16	0.17	0.15
25	8.33	8.35	8.36
50	16.53	16.59	16.53
75	24.69	24.71	24.69
100	33.02	33.05	32.99

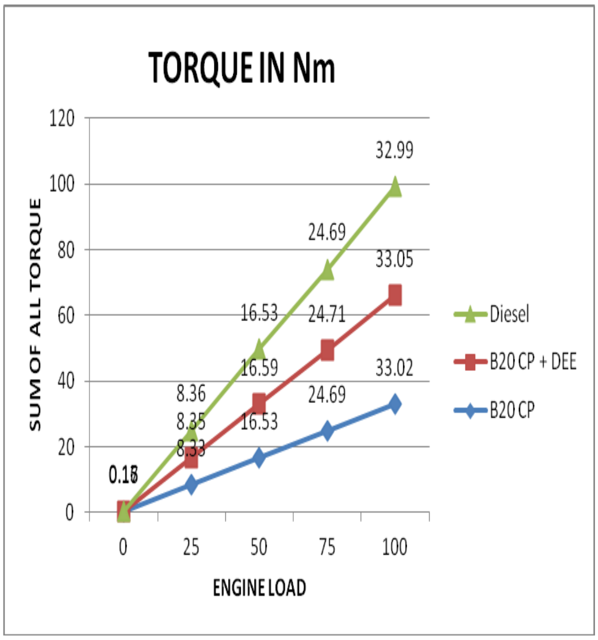

Figure 14: Engine Load - Engine Torque in Nm.

Discussion:

Table: 15 – Engine Torque - Comparison – B20 with NP and CP in % with D100+NP.

B20 CP vs D100 NP (in %)	B20 CP + DEE vs D100 NP (in %)
6.67	13.33
-0.36	-0.12
0.00	0.36
0.00	0.08
0.09	0.18
+ Increase, - Decrease	

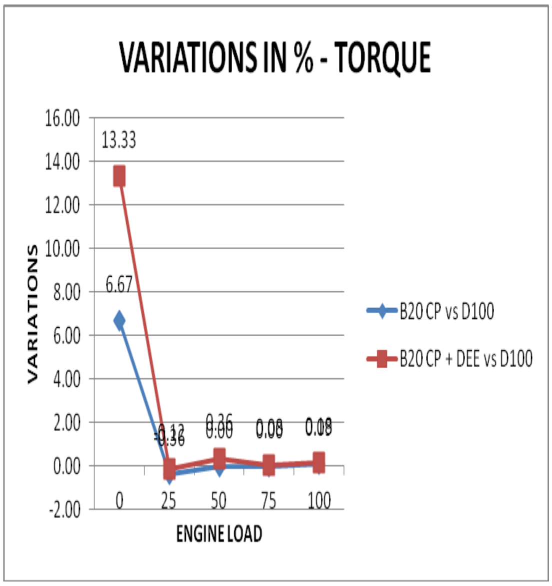

Figure 15: Variations – Engine Torque in Nm.

For B20+CP+DEE, 13.33% increase in engine torque is found at 0% engine load. At 25% load, 0.12% reduction in torque is found. At other loads, torque has increased.

VII. EMISSION CHARACTERISTICS

A. CARBON MONOXIDE (CO)

Emission of carbon monoxide takes place due to incomplete combustion.

Table 16: CO in %.

Engine Load in %	B20 CP	B20 CP + DEE	Diesel NP
0	0.079	0.012	0.029
25	0.054	0.016	0.037
50	0.062	0.016	0.024
75	0.068	0.026	0.031
100	0.289	0.166	0.181

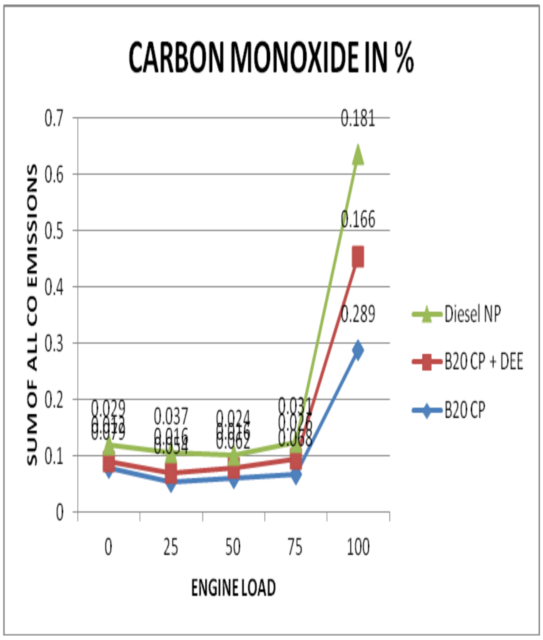

Figure 16: Engine Load - CO emission in %.

Result:

Table: 17 – CO emissions- Variations

B20 CP vs D100 NP (in %)	B20 CP + DEE vs D100 NP (in %)
172.41	-58.62
45.95	-56.76
158.33	-33.33
119.35	-16.13
59.67	-8.29
+ Increase, - Decrease	

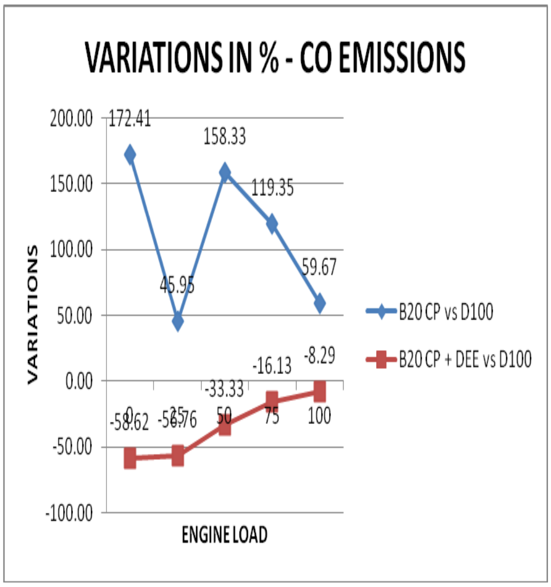

Figure 17: Engine Load - CO emission in %.

For B20+CP+DEE, considerable reduction in emissions of carbon monoxide is found at all loads. This is due to complete burning of fuel.

B. CARBON DIOXIDE (CO_2)

Incomplete combustion of fuel and presence of excess oxygen may lead to emission of carbon dioxide.

Table 18: CO_2 in %.

Engine Load in %	B20 CP	B20 CP + DEE	Diesel NP
0	2.26	1.79	1.78
25	4.46	3.96	3.91
50	6.23	5.69	5.92
75	8.34	7.82	7.42
100	10.8	10.3	9.52

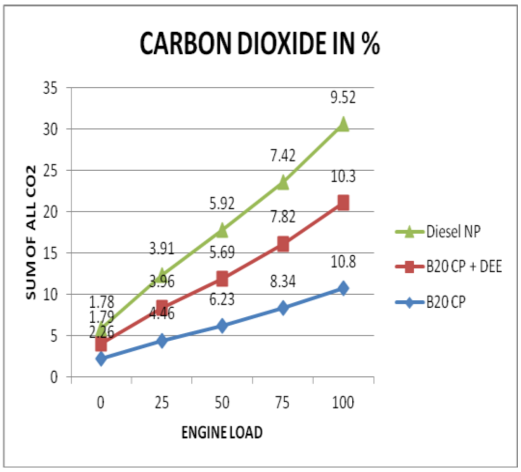

Figure 18: Engine Load - CO_2 emission in %.

Result:

Table: 19 – Variations – CO.

B20 CP vs D100 NP (in %)	B20 CP + DEE vs D100 NP (in %)
26.97	0.56
14.07	1.28
5.24	-3.89
12.40	5.39
13.45	8.19
+ Increase, - Decrease	

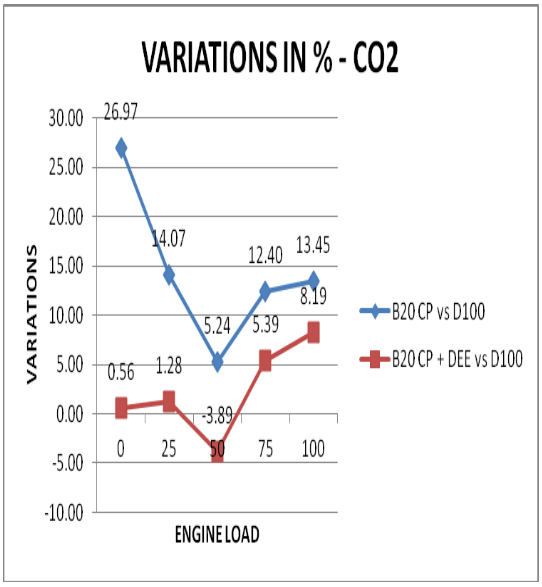

Figure 19: CO_2 emission.

In comparison to B20+CP+DEE, considerable reductions of CO_2 emission is found at all load.

C. Hydrocarbons (HC)

The reason for heavy smog in the atmosphere is emission of hydrocarbons by industries and automobiles. It is due to the unburned fuel left in the combustion chamber.

Table 20: HC in ppm.

Engine Load in %	B20 CP	B20 CP + DEE	Diesel NP
0	30	8	6
25	24	20	17
50	31	28	25
75	35	34	34
100	59	52	54

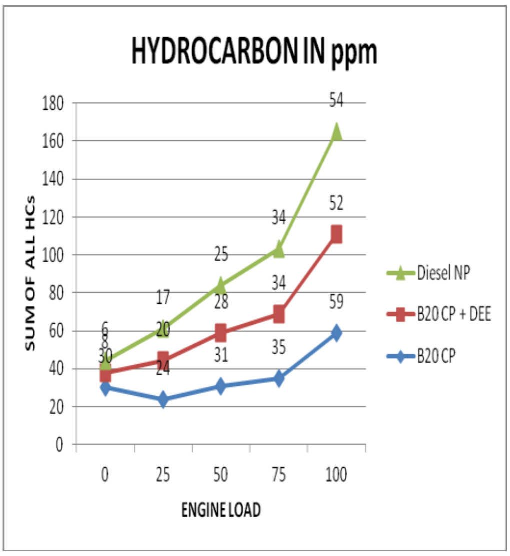

Figure 20: Engine Load vs Hydrocarbons (HC) emission in ppm.

Retrieval Number: E2792039520/2020©BEIESP
DOI: 10.35940/ijitee.E2792.039520
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Result:

Table: 22 – HC - Comparison – B20 with NP and CP in % with D100+NP.

B20 CP vs D100 NP (in %)	B20 CP + DEE vs D100 NP (in %)
400.00	33.33
41.18	17.65
24.00	12.00
2.94	0.00
9.26	-3.70
+ Increase, - Decrease	

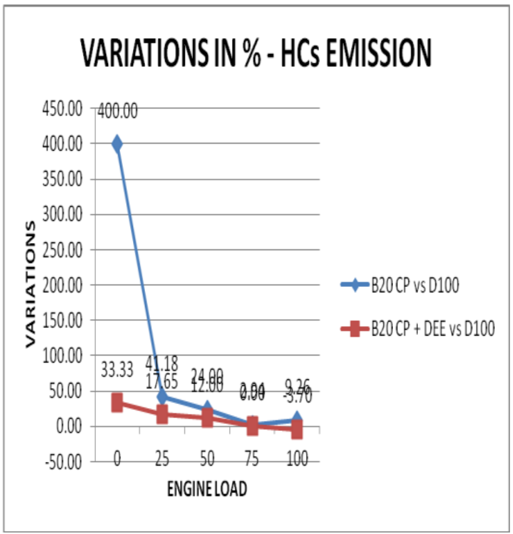

Figure 13: Engine Load - Hydrocarbons (HC) emission in ppm .

For B20+CP+DEE, considerable reduction in hydrocarbon emissions is found at all loads in comparison to B20+CP.

D. Oxides of Nitrogen (NO_X)

Oxides of nitrogen emission occur at high temperature. The nitrogen in air gets dissociated and combines with oxygen to form oxides of nitrogen.

Table 23: NO_X in ppm.

Engine Load in %	B20 CP	B20 CP + DEE	Diesel NP
0	131	121	94
25	593	524	462
50	967	888	849
75	1387	1285	1203
100	1500	1463	1421

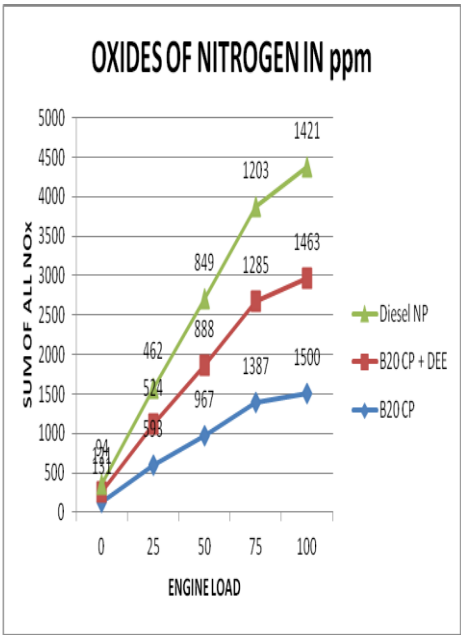

Figure 23: Engine Load - Oxides of Nitrogen in ppm.

Result:

Table: 24 – Variations - NO_X.

B20 CP vs D100 NP (in %)	B20 CP + DEE vs D100 NP (in %)
39.36	28.72
28.35	13.42
13.90	4.59
15.30	6.82
5.56	2.96
+ Increase, - Decrease	

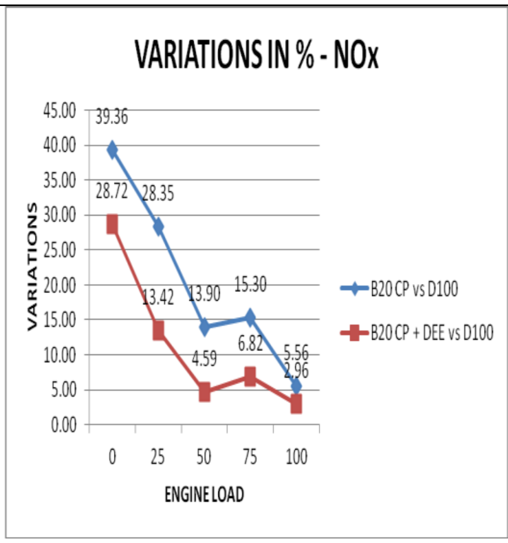

Figure 24: Engine Load - Oxides of Nitrogen in ppm.

For B20+CP+DEE, considerable reduction in emissions of oxides of nitrogen is found at all loads in comparison to B20+CP.

VIII. CONCLUSION AND FUTURE SCOPE

The necessity to find some renewable sources of energy is the prime concern for all engineers and environmentalists at present. Algae oil has proved to be a strong competent for alternative fuel whose characteristics can be improved at par with the pure fossil fuel diesel by using some techniques. In this paper, the algae biodiesel blend B20 is tested for its combustion and emission characteristics with 200 micron zirconium oxide thermal barrier coating on piston crown. The blend B20 is added with 10% diethyl ether as additive in order to improve combustion characteristics. Thermal barrier coating retains and prevents heat loss thereby making more heat to convert in useful work in addition to facilitate for complete combustion by increasing temperature of the mixture. The experimental results obtained with B20+CP+DEE is compared with the corresponding characteristics of pure diesel with normal cast aluminium alloy piston used in almost all automobiles.

The results have been found encouraging and in many cases, improvements in performance are observed. 100 % increase in brake power is observed. SFCs have also reduced due to increased volatility and flammability effect of diethyl ether. The emissions of major pollutants have reduced considerably. The emission of oxides of nitrogen has increased but it is lesser in comparison to the emissions of B20+CP without DEE.

The combustion and emission characteristics can further be improved in future by using the technique of pre-mixed charge compression.

REFERENCES

1. D.H. Qi, H. Chen, L.M. Geng, Y.Z. Bian, Effect of diethyl ether and ethanol additives on the combustion and emission characteristics of biodiesel-diesel blended fuel engine, International Journal of Renewble Energy, 2010.
2. S. Sendilvelan, K. Bhaskar, Studies on the enhancement of diesel engine combustion through the use of pib-succinimide type fuel additive and internal jets for turbulence inducement to reduce environmental pollution, International Journal of Chem. Sci, 2016.
3. Krishnamoorthi S, Prabhahar M, Saravanakumar M, Sendilvelan S, Yield characteristic of biodiesel derived from used vegetable oil methyl ester (UVOME) blended with diesel, in the presence of sodium hydroxide (NAOH) and potassium hydroxide (KOH) catalyst, as alternative fuel for diesel engines, IJMPERD, 2018.
4. Bhaskar K, Sassykova L. R, Prabhahar M, Sendilvelan S, Effect of dimethoxy-methane ($C_3H_8O_2$) additive on emission characteristics of a diesel engine fueled with biodiesel, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), 2018.
5. Faqih Fatkhurrozak, Syaiful, Effect of Diethyl Ether (DEE) on Performances and Smoke Emission of Direct Injection Diesel Engine Fueled by Diesel and Jatropha Oil Blends with Cold EGR System, International Conference on Mechanical Engineering Research and Application, 2019.
6. R. Sathiyamoorthi, G. Sankaranarayanan, K. Pitchandi, Combined effect of nanoemulsion and EGR on combustion and emission characteristics of neat lemon grass oil (LGO)-DEE-diesel blend fuelled diesel engine", Applied Thermal Engineering, 2017.
7. J. Kuberan and N. Alagumurthi: Performance and Emission Characteristics of Algae Bio-fuelled Diesel Engine, Int. J. Chem. Sci.: 14(4), 2016.
8. Amr Ibrahim, Investigating the effect of using diethyl ether as a fuel additive on diesel engine performance and combustion, Applied Thermal Engineering, 2016.
9. Gangadhara Rao, Kumar G N, Mervin Herbert, Effects of Additives on Biodiesel/Diesel Performance, Emission Characteristics, Combustion Characteristics and Properties, National Conference on Advances in Mechanical Engineering Science (NCAMES-2016), National Institute of Technology Karnataka, Surathkal., India.
10. G. Nagane and C. Choudhari, Emission Characteristics of Diesel Engine Fueled with Algae Biodiesel –Diesel Blends, IRJET, 2015.

AUTHOR PROFILE

Mr. Sanjay Singh an employee of Vinayaka Mission's Kirupananda Variyar Engineering College, Salem, Tamil Nadu, India has a rich experience in maintenance of internal combustion engines especially in engines used in aircrafts like jet engines. Published papers in international journals related to his research work especially on alternative fuel.

Dr. M. Prabhahar is a distinguished Professor in Aarupadai Veedu Institute of Technology, Chennai, Tamil Nadu, India and is working in Department of Mechanical Engineering. He is reviewers of many international journals and has many research scholars are being guided by him. Awarded with several citations and prizes, he is consistently working and contributing in research. His area of research is alternate fuels.