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.

Keywords: 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 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.

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 transesterification 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 °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 C₄H₉OC₂H₅. 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 cm³ |
| 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 - 40°C | Algae Biodiesel | ASTM Standards - Diesel |
|--------|-------------|--------------------------|----------------|-------------------------|
| 1.     | Nature of Sample | B100 | D100 |
| 2.     | Kinematic Viscosity - cSt | 4.07 | 2 - 4.5 |
| 3.     | Density -Kg/m³ | 896 | 820 – 860 |
| 4.     | Fire Point - °C | 119 | 210 |
| 5.     | Flash Point - °C | 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      |
Result:

Table: 5 – BP - Variations.

| Engine Load in % | B20 CP vs D100 NP (in %) | B20 CP + DEE vs D100 NP (in %) |
|------------------|--------------------------|---------------------------------|
| 50.00            | 0.00                     | -0.39                           |
| 75.00            | 1.58                     | 1.60                            |
| 100.00           | 3.14                     | 3.16                            |

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.

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      |

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.

| 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    |

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.

| 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 8: Engine Load - BTE

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

Figure 9: 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 10: Engine Load – SFC

Result:
Table 11 – Variations - SFC

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

+ Increase, - Decrease
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     |

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     |

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

Retrieval Number: E2792039520/2020©BEIESP
DOI: 10.35940/ijitee.E2792.039520

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     |

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 %.

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.

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                           |

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                          |
| 42.00                    | 12.00                          |
| 2.94                     | 0.00                           |
| 9.26                     | -3.70                          |

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

**D. Oxides of Nitrogen (NO\textsubscript{X})**

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

| 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     |

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

**VIII. RESULT**

The experimental results obtained with addition of diethyl ether as additive and using 200 micron stabilize zirconia piston clearly indicates improvement in performance and emission characteristic of the compression ignition engine. Brake Power also increase with increasing load. Brake specific fuel consumption decreased with increasing load and brake power. Emissions of carbon dioxide, hydrocarbons and oxides of nitrogen have increased in comparison to reference fuel diesel but reduced than B20 alone with coated piston.

**IX. 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+CF 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 Renewable 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, Sendivelan 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, IMPERD, 2018.

4. Bhaskar K, Sassykova L R, Prabhahar M, Sendivelan S. Effect of dimethoxy-methane (C3H8O2) additive on emission characteristics of a diesel engine fueled with biodiesel, International Journal of Mechanical and Production Engineering Research and Development (IMPERD), 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. Sathiyaamoorthi, 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. Gangadhar 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 (NCAVES-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.