Emission characteristics of spirulina biodiesel with single hole nozzle

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Abstract. Diesel engines are well known for their high efficiency and durability. At the same time they are considered to be one of the largest contributors to environmental pollution. It is mainly due to their exhaust emissions. These exhaust emissions are responsible for many health issues to man and environment. The polluted climate change has forces the researchers to find the alternative, less carbon fuel. This paper aims at analyzing the emission characteristics of spirulina biodiesel with single hole nozzle. Transesterification methods are used during biodiesel production. The biodiesel is tested in Four Stroke, single cylinder variable comparison engine (VCR). The rated speed of the engine is 1500rpm at different loads.

Key words: Transesterification, Biodiesel, Spirulina biodiesel, Emission

1. Introduction

Increase in population has paved way to increase in transport. The main fuel that is involved in majority of vehicle is diesel. On the other hand the emission from the diesel engine has contributed to half amount of nitrogen components and particulate matter emitted by vehicles [1]. These emissions results in many air pollution problems including the acid rain, smog, pollution of air, water contamination, soil degradation and global climate changes. Apart from the environmental the diesels emissions also contribute serious effect to human health like cancer, respiratory problems and cardio vascular issues. Slowly moving towards renewable alternative fuels like bio fuels is one of the effective ways to reduce the emission of the harmful gases. Though there are other ways like using electrical vehicle might be a solution to reduce emission due to the high cost and lack of charging network infrastructure, biodiesel are proved to a better option [2]. They can be used the diesel engine, with or with blending with diesel. Biodiesel has many advantages when compared with diesel. The emissions has less carcinogenic substances with has reduced less toxicity when compared with diesel exhaust [3].

Biodiesels are bio fuels that are obtained from chemical processing of vegetable oils, algae oils and animals fats [4]. Among the various algae from which biodiesel can be produced spirulina, commonly known as blue-green algae is the best source as it has high oil yield nature. As it can be grown in both fresh water and salt water cultivation of spirulina is easy [5]. Similar to plants spirulina produces its food from sunlight [6].

In this study the biodiesel produced from Spirulina microalgae bio-oil is blended with 20 % and 40 % diesel and compared with diesel in VCR engine at various load using single hole nozzle. The emission characteristics of Hydro Carbon, Carbon Monoxide, Carbon dioxide, Nitric acid, Smoke density and brake thermal efficiency are analyzed.

2. Experimental setup.

For this study single cylinder, four stroke variable compression ratio (VCR) engines are used.
As shown in Fig.1 the engine is two separation input cylinder for biodiesel and diesel, stand alone panel box, process indicator and engine indicator [7]. The input is monitored by the sensor fixed with the cylinder. The engine consists of specially designed tilting cylinder arrangement. In Fig.2, this arrangement makes feasible in changing the compression ratio without physically stopping the engine.

![Fig. 1. Working process of diesel engine](image)

Fig. 1. Working process of diesel engine

For measuring the combustion pressure and crank angle the necessary setup is made. The output signals are transmitted to computer monitor through interface. There are provisions to measure the air flow, flue flow and temperature flow [8]. The cooling water and calorimeter water flow is measured using Rota meter. This setup enables to study the brake power performance, frictional power, indicated power, brake thermal efficiency, mechanical efficiency and specific fuel consumption.

![Fig. 2. VCR Engine](image)

Fig. 2. VCR Engine

3. Emission Analyzer
The constituent of the exhaust like Hydro Carbon, Carbon Mono Oxide, Carbon dioxide, Oxygen and Nitric Oxide are measured by Gas Analyzer [9]. Hydro Carbon, Carbon Mono Oxide, Carbon dioxide are measured using Non-Scattering infrared but Oxygen and Nitric Oxide are measured using electro-chemical technique. The indented measurement for Hydro Carbon and Nitric Oxide is 1ppm and for Carbon monoxide, Carbon dioxide, Oxygen it is 0.01% each [10].

4. Gas Analyzer Specifications (Type AVL DIGAS)
The exhaust as is transferred through the filter. The unused waste minute particles are removed here. Then the moist particles are removed b the cold traps. Then the gas is transferred to the
exhaust gas analyzer. Here the fixed sensor measures the reading. The readings are displayed in
the monitor. It can be recorded in the memory also.

The specifications of the various exhaust gases are mentioned in Table 1.

**Table- 1: The measured values of exhaust and measurement ranges**

| EXHAUST GAS | MEASUREMENT RANGE |
|-------------|--------------------|
| CO          | 0-10 vol. %        |
| HC          | 0-20,000 ppm       |
| CO2         | 0-20 vol. %        |
| O2          | 0-22 vol. %        |
| NOx         | 0-5000 ppm         |

5. Results and discussion

5.1. CO for Spirulina and diesel VS Load

From the table 2 and figure 3, it shows that Carbon monoxide emission with the single hole
nozzle has the highest emission 0.038, 0.045 and 0.047 for corresponding 20%, 40% and Diesel for various loads. Among the shown various percentage mixture it is found that Diesel emits more CO compared to other.

**Table- 2: the measured output values of CO for Spirulina and diesel versus Load**

| SL.NO | Load | Bio fuel mixture with diesel | 20% | 40% | diesel |
|-------|------|------------------------------|------|-----|--------|
| 1     | 0    | 0.012                        | 0.015| 0.017|
| 2     | 3    | 0.017                        | 0.019| 0.021|
| 3     | 6    | 0.025                        | 0.028| 0.031|
| 4     | 9    | 0.038                        | 0.045| 0.047|

**Fig. 3. Variation of CO for Spirulina and Diesel with Load**

5.2. HC for Spirulina and Diesel VS Load

From the table 3 and figure 4, it shows that Hydro Carbon emission with the single hole nozzle
has the lowest emission, 2.64, 3.2 and 3.7 for corresponding 20%, 40% and Diesel for various loads. Among the shown various percentage mixture it is found that Diesel emits more HC compared to others.
Table-3: The results of HC for Spirulina and Diesel versus Load.

| SL.NO | Load | Bio fuel mixture with diesel |
|-------|------|-----------------------------|
|       |      | 20% | 40% | diesel |
| 1     | 0    | 8   | 8.2 | 8.5   |
| 2     | 3    | 7.3 | 7.5 | 7.9   |
| 3     | 6    | 5.5 | 5.9 | 6.12  |
| 4     | 9    | 2.64| 3.2 | 3.7   |

Fig. 4. Variation of HC for Spirulina and Diesel with Load

5.3. CO\textsubscript{2} for Spirulina and Diesel VS Load
From the table 4 and figure 5, it shows that Carbon Dioxide with the single hole nozzle has the highest emission, 2.2, 2, and 2.4 for corresponding 20%, 40% and Diesel for various loads. Among the shown various percentage mixture it is found that Diesel emits more CO\textsubscript{2} compared to others.

Table-4: CO\textsubscript{2} for Spirulina and Diesel vs Load

| SL.NO | Load | Bio fuel mixture with diesel |
|-------|------|-----------------------------|
|       |      | 20% | 40% | diesel |
| 1     | 0    | 0.6 | 0.65| 0.8   |
| 2     | 3    | 0.9 | 1.2 | 1.4   |
| 3     | 6    | 1.2 | 1.5 | 1.7   |
| 4     | 9    | 2   | 2.2 | 2.4   |

Fig. 5. Variation of CO\textsubscript{2} for Spirulina and Diesel with Load
5.4. O$_2$ for Spirulina and Diesel VS Load
From the table 5 and figure 6, it shows that Oxygen with the single hole nozzle has the highest emission of 18.18, 18.92 and 20.99 for corresponding 20%, 40% and Diesel for various loads. Among the shown various percentage mixture it is found that Diesel emits more O$_2$ compared to others.

| SL.NO | Load | Bio fuel mixture with diesel |
|-------|------|-----------------------------|
|       |      | 20% | 40% | diesel |
| 1     | 0    | 16  | 16.8| 17.7   |
| 2     | 3    | 17.23 | 18.3| 19.53  |
| 3     | 6    | 17.42 | 18.75| 19.09  |
| 4     | 9    | 18.18 | 18.92| 20.99  |

![Fig. 6. Variation of O$_2$ for Spirulina and Diesel with Load](image)

5.5. NO$_x$ for Spirulina and Diesel VS Load
From the table 6 and figure 7, it shows that Nitric Oxide with the single hole nozzle has the highest emission of 221, 232 and 272 for corresponding 20%, 40% and Diesel for various loads. Among the shown various percentage mixture it is found that Diesel emits more NO$_x$ compared to others.

| SL.NO | Load | Bio fuel mixture with diesel |
|-------|------|-----------------------------|
|       |      | 20% | 40% | diesel |
| 1     | 0    | 22  | 29  | 38     |
| 2     | 3    | 101 | 168 | 194    |
| 3     | 6    | 167 | 182 | 222    |
| 4     | 9    | 221 | 232 | 272    |
5.6. Smoke Density for Spirulina and Diesel VS Load
From the table 7 and figure 8, it shows that Smoke Density with the single hole nozzle has the highest emission of 40.9, 44.8 and 46.8 for corresponding 20%, 40% and Diesel for various loads. Among the shown various percentage mixture it is found that Diesel emits more Smoke Density compared to others.

**Table- 7: The smoke density for Spirulina and Diesel versus Load**

| SL.NO | Load | Bio fuel mixture with diesel |
|-------|------|-----------------------------|
|       |      | 20% | 40% | diesel |
| 1     | 0    | 25.1 | 29.1 | 30.8 |
| 2     | 3    | 26.4 | 30.1 | 31.8 |
| 3     | 6    | 32.5 | 35.8 | 40.2 |
| 4     | 9    | 40.9 | 44.8 | 46.8 |

5.7. Specific Fuel Consumption (SFC) for Spirulina and Diesel VS Load
From the table 8 and figure 9, it shows that Specific Fuel Consumption with the single hole nozzle has value of 0.33, 0.33 and 0.35 for corresponding 20%, 40% and Diesel for various loads. Among the shown various percentage mixture it is found that Diesel has more Specific Fuel Capacity compared to others.
Table- 8: The SFC for Spirulina and Diesel versus Load

| SL.NO | Load | Bio fuel mixture with diesel |
|-------|------|-----------------------------|
|       |      | 20% | 40% | diesel |
| 1     | 0    | 0   | 0   | 0     |
| 2     | 3    | 0.6 | 0.61| 0.63  |
| 3     | 6    | 0.26| 0.29| 0.37  |
| 4     | 9    | 0.33| 0.33| 0.35  |

Fig. 9. Variation of SFC of Spirulina & Diesel with Load

5.8. Brake Thermal Efficiency (BTE) for Spirulina and Diesel VS Load
From the table 9 and figure 10, it shows that Break thermal Efficiency with the single hole nozzle has the highest value of 25.8, 24.8 and 22.9 for corresponding 20%, 40% and Diesel for various loads. Among the shown various percentage mixture it is found that 20% biodiesel mixture with Diesel has more Break thermal Efficiency compared to others.

Table- 9 : The BTE for Spirulina and Diesel versus Load

| SL.NO | Load | Bio fuel mixture with diesel |
|-------|------|-----------------------------|
|       |      | 20% | 40% | diesel |
| 1     | 0    | 0   | 0   | 0     |
| 2     | 3    | 18.6| 14.1| 15.5  |
| 3     | 6    | 22.2| 23.2| 21.3  |
| 4     | 9    | 25.8| 24.8| 22.9  |

Fig. 10. Variation of BTE for Spirulina and Diesel with Load
6. Conclusion

The above experiment is to examine the emission characteristics of Spirulina oil blend with diesel at different loads using single hole nozzle. The testing was done in VCR engine (1500 rpm) at various ratios. From the obtained results it is found that Spirulina oil is one of the best alternative fuel for diesel.

From the above investigation the below results are obtained,

- Spirulina oil is a promising alternative fuel for diesel.
- Spirulina biodiesel can be used directly or blended with diesel in CI engine with or without any modifications.
- The above testing results prove the Hydro Carbon is decreasing with load.
- Carbon Monoxide, Nitric Oxide, Carbon dioxide, Smoke density and Brake thermal efficiency are increasing with load.

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