Performance Analysis of a Single Cylinder Four Stroke Diesel Engine Using Sunflower Oil as a Biodiesel Blend: An Experiment

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Abstract - With the growth of modern civilization and industrialization in worldwide, the demand for energy is increasing day by day. Majority of the world's energy needs are met through fossil fuels and natural gas. As a result the amount of fossil fuels is on diminishing from year to year. Since the fossil fuel is non renewable, so fuel price is going as a consequence of spiraling demand and diminishing supply. At present the power generation of our country is mainly depends on imported fossil fuels. To reduce the dependency on imported fuel, the use of renewable sources has become more popular. In India, Sunflower is widely growing plant. Especially in the southern part of the country a large area will be found where sunflower plant is considered as natural asset. So, our Endeavour was to use the sunflower oil as a renewable and alternative fuel. This article shows the prospect of sunflower oil as a renewable and alternative fuel of diesel fuel. Since diesel engine has a versatile uses including small electricity generation, an experimental set up is then made to study the performance of a small diesel engine using different blends of bio diesel converted from sunflower oil. It is found that bio diesel has slightly different properties than diesel. With biodiesel the engine is capable of running without difficulty. Different blends of bio diesel (i.e. b80, b60, and b50 etc.) have been used to avoid complicated modification of the engine or the fuel supply system. Finally, a comparison of engine performance for different blends of biodiesel has been carried out to determine the optimum blend for different operating conditions.

Keywords – Biodiesel, Bio-fuel, Renewable Energy, Transesterification, sunflower oil as an alternative fuel

I. INTRODUCTION

1.1 History of Biodiesel

Dr. Rudolf Diesel invented the first diesel engine in 1892 and it was designed to run on a number of fuels including vegetable oil. He developed the diesel engine to run-on vegetable oil and commented that it would help considerably in the development of agriculture of the countries that use it. He demonstrated his engine at the World Exhibition in Paris in 1900 and described an experiment using peanut oil as fuel in his engine. Biodiesel has actually been around for around 100 years but the cheap availability of petroleum fuel has made it the choice for diesel fuel. But now petrol and diesel prices have raised to such a high level, it's becoming affordable to use biodiesel. And it's becoming very popular in many countries across the globe. As early as the 1930s, there was interest in splitting the fatty acids from the glycerin in vegetable oil in order to create a thinner product similar to petroleum diesel. In 1937, G. Chavannes was granted a Belgian patent for an ethyl ester of palm oil (which today we would call biodiesel). In 1938, a passenger bus fuelled with palm oil ethyl ester plied the route between Brussels and Louvain. During World War II (1939 to 1945), when petroleum fuel supplies were interrupted, vegetable oil was used as fuel by several countries, including Brazil, Argentina, China, India, and Japan. However, when the war ended and petroleum supplies were again cheap and plentiful, vegetable oil fuel was forgotten.

1.2 Biodiesel

Biodiesel, a diesel fuel substitute that can be made from a variety of oils, fats, and greases, is of interest to farmers for a number of reasons. It can provide an additional market for vegetable oils and animal fats, it can allow farmers to grow the fuel they need for farm machinery and can decrease dependence on imported oil since fuel feed stocks can be grown domestically. Biodiesel is a renewable source of energy that can help reduce green house gases and minimize the "carbon footprint" of agriculture. It contributes less to global warming because the carbon in the fuel was removed from the air by the plant feedstock. In addition, biodiesel produces less air pollution (exhaust emissions) than diesel made from fossil fuels. Raw Materials for Biodiesel Production are Crude rapeseed oil, Rapeseed oil, used cooking oil, Soybean oil, Palm oil, Jatropha oil, Peanuts and sunflower oil. Sunflower oil: Sunflower oil is a vegetable oil extracted from the seeds of the sunflower and is the vegetable oil which is number four in production capacity worldwide

Athanasios Balafoutis et al[1] conducted a comparative experimental investigation to evaluate the performance and exhaust emissions of an agricultural tractor engine when fueled with sunflower oil, rapeseed oil, and cottonseed oil and their blends with diesel fuel (20/80, 40/60 and 70/30 volumetrically). Tests were also carried out with diesel fuel to be used as a reference point. Engine power, torque, BSFC, thermal efficiency, NOx and CO2 were recorded for each tested fuel. Rapeseed oil fuels showed increased power, torque and thermal efficiency with simultaneous lower BSFC in comparison to the other two vegetable oils. Cottonseed oil fuels gave better engine performance than sunflower oil fuels. In all oil types, NOx emissions were augmented when fuel oil percentage was increased. Cottonseed oil fuels led to higher NOx emission increase compared to rapeseed oil fuels. CO2 emissions showed a tendency to be increased as the oil content was evolved. The highest CO2 emissions were given by cottonseed oil fuels, followed by rapeseed and sunflower oil. **Rehab FM Ali et al [2]** did an experiment on blends where their results showed that phenolic content of cold pressed tiger nut oil was about 3.3 times higher than that of sunflower oil. **M. Thirumarimurugan et al [3]** converted waste sunflower oil used for domestic purposes such as cooking oil into biodiesel using an alkali catalysed transesterification process. This article reports experimental data on the production of fatty acid methyl esters from sunflower oil using sodium hydroxide as alkaline catalyst. From the results it was clear that the produced biodiesel fuel was within the recommended standards of biodiesel fuel The process involves heating of oil, followed by titration, then settling and separation and finally washing.It was concluded that sunflower oil is one of the option for biodiesel production at a large scale depending on its mass cultivation.

1.3 Advantages of Bio-Fuels

As of now, bio-fuels cost the same in the market as gasoline does. However, the overall cost benefit of using them is much higher. They are cleaner fuels, which mean they produce fewer emissions on burning. Bio-fuels are made from many different sources such as manure, waste from crops and plants grown specifically for the fuel. Most of the fossil fuels will expire and end up in smoke one day. Since most of the sources like manure, corn, switch grass, soya beans, waste from crops and plants are renewable and are not likely to run out any time soon, making the use of bio-fuels efficient in nature. These crops can be replanted again and again. Studies suggest that bio-fuels reduce greenhouse gases up to 65 percent. If more people start shifting towards bio-fuels, a country can reduce its dependence on fossil fuels. Since bio-fuels can be made from renewable resources, they cause less pollution to the planet. They also release lower levels of carbon dioxide and other emissions when burnt. Bio-fuels like ethanol and biodiesel are better for car engines than fossil fuels. Biodiesel is a better lubricant than petro-diesel, so it helps to extend the working life of engines.

1.4 Disadvantages of Bio-Fuels

Biodiesel can gel in colder weather. Gelling is what often takes place in biodiesel fuel in colder climates. There is a certain temperature where biodiesel fuel begins to gel, which can hinder use. Many producers have been unable to produce biodiesel that meets ASTM 6751 quality due primarily to their inability to remove all impurities and water during the washing and refining processes. The EPA found that the use of B20 can reduce fuel efficiency by 1 to 2%. Bio-fuels are produced from crops and these crops need fertilizers to grow better. The downside of using fertilizers is that they can have harmful effects on surrounding environment and may cause water pollution.

1.5 Biodiesel Blend

Although the Biodiesel fuel can be used in its pure form, more common use of it is seen as biodiesel blends or blended with petroleum fuel. The most common mix or biodiesel fuel blends is referred to as "B20" containing 20% biodiesel by volume, and 80% petroleum. All over the world, the system of the "B" factor is used to state the quantity of biodiesel in any fuel mix. For example, B100 would mean a 100% biodiesel, while a 20% biodiesel fuel blends is labeled B20. Similarly, 5% biodiesel is labeled B5 and 2% biodiesel is labeled B2.The greater the percentage of biodiesel fuel in its blend, the more ecology-friendly is the fuel. In US, it is common to see B99.9 because a federal tax credit is awarded to the first entity which blends petroleum diesel with pure biodiesel fuel. Biodiesel blends of 20 percent biodiesel with 80 percent petroleum diesel (B20) can usually be used in unmodified diesel engines.

1.6 Preparation Methods

Blending biodiesel with petroleum diesel may be mixed by following methods:

- Mixing in tanks at manufacturing point prior to delivery to tanker truck.
- Splash mixing in the tanker truck.

- In-line mixing, two components arrive at tanker truck simultaneously.
- Metered pump mixing petroleum diesel and biodiesel meters are set to X total volume, transfer pump pulls from two points and mix is complete on leaving pump.
- The general method.

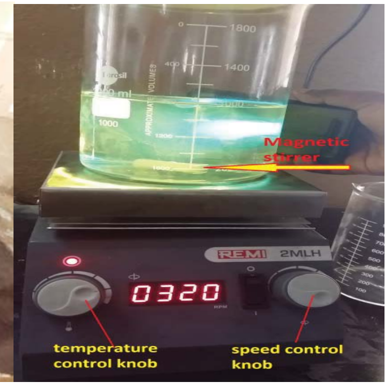


Fig 1.1 Equipment for Bio-Diesel Preparation

Fig 1.2 Heater with temperature and speed controls

1.7 The General Method

The general method that followed is by mixing and simultaneous heating of the diesel and sunflower oil. The equipment required for the preparation of a blend is as follows:

1. Heater (in connection with magnetic motor).
2. 1000 ml beaker, 800 ml beaker, 50 ml beaker.
3. Pipette (connected with bubbler).
4. Thermometer.
5. Magnetic stirrer.
6. Three one-liter empty bottles.
7. Cone filter.
8. Four liters Petroleum Diesel.
9. One liter extracted sunflower oil.

II. EXPERIMENTAL PROCEDURE & RESULTS

EXPERIMENTAL PROCEDURE

2.1 Procedure for preparing Sunflower Blend

Take 900ml of diesel oil with the help of cone filter. Take 100ml of sunflower oil with the help of a pipette and mix it into 1000ml beaker for preparing a B10 blend. Put the heater to lowest temperature, by control knob. Now take the 1000ml beaker onto the heater and start heating by switching on the heater. Increase the speed of the motor, by controlling the speed knob and maintain a constant speed of 380rpm where the magnetic stirrer rotates which helps in proper mixing of diesel oil and sunflower oil. Continue the procedure until the temperature of the mixture reaches desired value by simultaneously increasing the temperature. After the temperature reaches desired value reduce the temperature back to initial condition and reduce the speed of the magnetic stirrer to zero. Switch off the instrument and remove the beaker from the heater. Place the beaker in an open atmosphere away from dust, and allow the mixture for natural cooling. After the mixture is cooled it is ready for testing. Repeat the same procedure for preparing B20 Blend.

2.2 Procedure for Performance Test

Fill up sufficient diesel in the diesel tank. Check oil level in the engine lubricating oil sump. If oil level is reduced, add up clean SAE 40 oil. Replace the cover after filling the oil. Fill up the oil in crank shaft journal bearing. If diesel tank is empty before filling the diesel, remove the air bubble, in fuel pipe by opening the tightening nut of diesel, remove air bubbles in the fuel pipe by pumping the hand lever provided. Release the loading screw so that there is no tension in the rope. Press down the de-compression lever below the cam. Put the handle over the starting shaft and rotate the shaft. As engine picks up sufficient speed, release the decompression lever and engine will start.

Remove the handle immediately. If the engine is cold, inlet air may be required to be heated with cotton wick immersed in diesel, burning at suction valves as the engine is indirect injection type. Run the engine for 15 minutes so that it can stabilize. Load the engine with loading screw, and set the spring balance difference to say 3kg. Open burette filling cock, take sufficient diesel in burette and close the cock. Now put off fuel cock on diesel tank side and note down time required for 10 ml fuel consumption from burette. Repeat the above procedure for different loads 3kgf, 6kgf, and 9kgf etc., and complete the observation table.

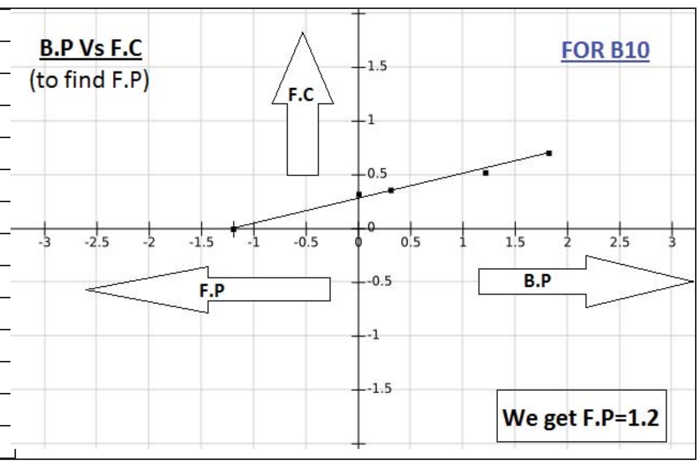
$$T= 1x\ 9.81x0.30239\ N\text{-}m$$

2.3 Procedure for finding emissions

Connect the INDUS 5 GAS ANALYSER (model PEA 205) to the experimental set up before starting the experiment, with switch off condition. Put the probe at the exhaust pipe of the experimental setup such that the copper cap of the probe is against to the flow of exhaust gases. Clamp the probe to the exhaust pipe using the spring loaded handle. Now switch on the analyzer, the analyzer will ask to elect the type of engine Press '2' to select 4- stroke engine. Again the analyzer asks to select vehicle number. Press '1' to select the first vehicle i.e., single cylinder diesel engine connected to the analyzer. After starting the engine, wait for the values to become constant. Note down the emission values for the CO, HC, CO_2, O_2, NO_X gases at zero load condition. Now set the readings again to initial condition by pressing zero buttons on the analyzer's selector panel. Repeat the above procedure and note down the readings for next load conditions.

S.NO	1	2	3	4	UNITS
Load	0	3	6	9	kgf
B.P	0	0.3057	1.2115	1.81727	kW
F.C	0.3233	0.3618	0.5242	0.7068	kg/hr
F.P	1.2	1.2	1.2	1.2	kW
I.P	1.2	1.8057	2.4115	3.01727	kW
B.S.F.C	-	0.5973	0.4326	0.3689	(kg/kW-hr)
I.S.F.C	0.2694	0.2003	0.2173	0.23425	(kg/kW-hr)
Hfull	13698	15329	22210	29947	kJ/hr
HB.P	0	2180.52	4361.4	6542.17	kJ/hr
HI.P	4320	6500.52	8681.4	10862.172	kJ/hr
ηmech	0	33.543	50.238	60.228	%
ηB.th	0	14.224	19.6368	21.845	%
ηI.th	31.536	42.405	39.087	36.271	%

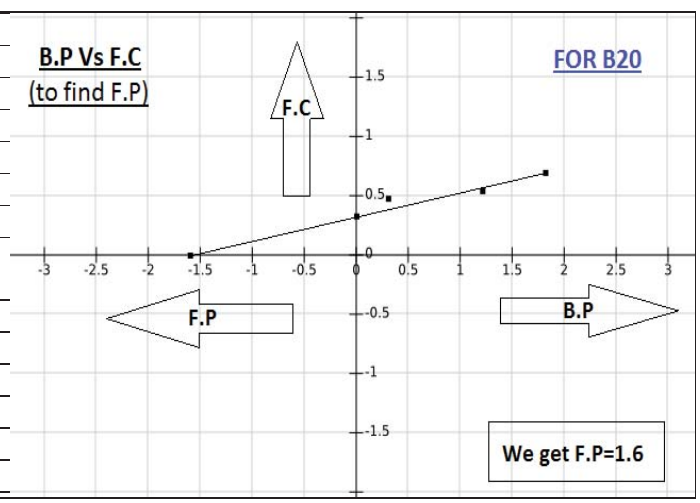
Table 2.1: Calculation Table for B10



Graph 2.1: Graph between B.P Vs F.C to find F.P for B10

S.NO	1	2	3	4	UNITS
Load	0	3	6	9	kgf
B.P	0	0.3057	1.2115	1.81727	kW
F.C	0.3299	0.4794	0.5440	0.6974	kg/hr
F.P	1.6	1.6	1.6	1.6	kW
I.P	1.6	2.2057	2.8115	3.41727	kW
B.S.F.C	-	0.7914	0.4523	0.38189	(kg/kW-hr)
I.S.F.C	0.20618	0.217345	0.1949	0.20408	(kg/kW-hr)
Hfull	13589	19746	22407	28725	kJ/hr
HB.P	0	2181	4361	6542	kJ/hr
HI.P	5760	7941	10121	12302	kJ/hr
ηmech	0	27.46	43.090	53.1789	%
ηB.th	0	11.0425	19.464	22.7744	%
ηI.th	42.388	40.2123	45.1699	42.8260	%

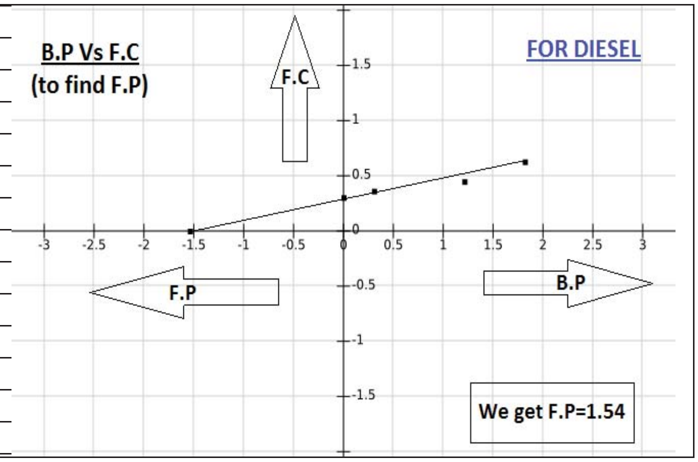
Table 2.2: Calculation Table for B20



Graph 2.2: Graph between B.P Vs F.C to find F.P for B20

S.NO	1	2	3	4	UNITS
Load	0	3	6	9	kgf
B.P	0	0.3057	1.2115	1.81727	kW
F.C	0.3038	0.3623	0.44857	0.628	kg/hr
F.P	1.54	1.54	1.54	1.54	kW
I.P	1.54	2.1757	2.7515	3.3572	kW
B.S.F.C	-	0.5981	0.3703	0.34557	(kg/kW-hr)
I.S.F.C	0.1972	0.166	0.1630	0.187	(kg/kW-hr)
Hfull	12760	15217	18840	26376	kJ/hr
HB.P	0	2180.52	4361.4	6542.53	kJ/hr
HI.P	5544	7832.52	9905.4	12085.92	kJ/hr
ηmech	0	27.8393	44.030	54.130	%
ηB.th	0	14.32	23.149	24.804	%
ηI.th	43.449	51.473	52.576	45.821	%

Table 2.3: Calculation Table for Diesel

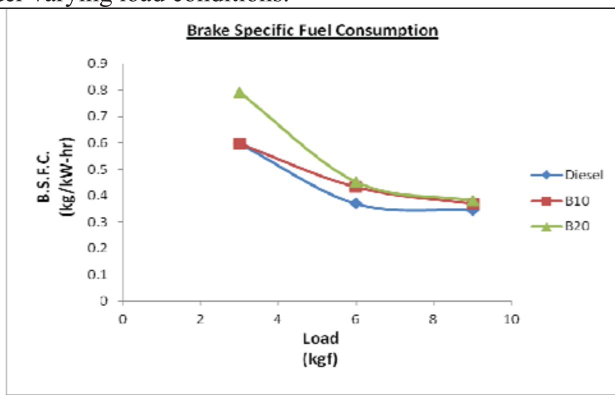


Graph 2.3: Graph between B.P Vs F.C to find F.P for Diesel

III. OBSERVATIONS FROM RESULTS

From the experimental calculations and results, the following graphs are obtained for Diesel, B10 and B20 Bio-fuel Blends under varying load conditions.

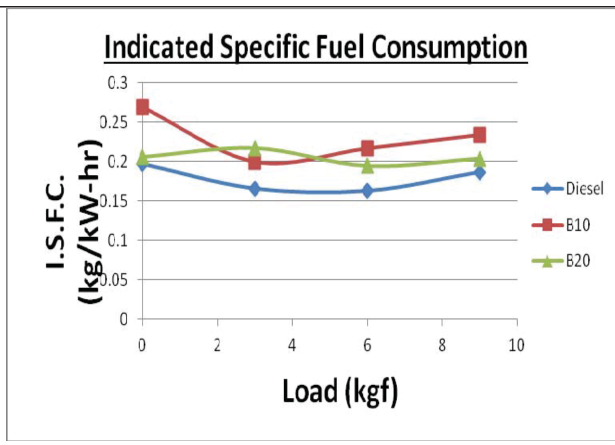
BSFC



Graph 3.1: Between load Vs B.S.F.C for all three fuels

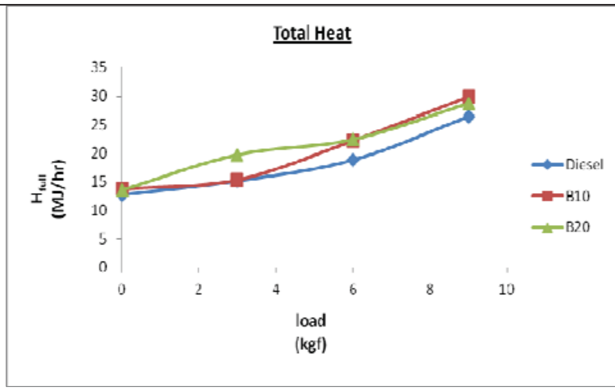
Initially B20 shows a large value of Brake Specific Fuel Consumption at lower load conditions, than that of B10 and Diesel. But, with increase in loading, B20 decreased heavily when compared to B10 and Diesel. This shows B20 is more effective at higher loads. This decrease can be even more with increase in load. Whereas B10 almost remains unchanged, with increase in load. Diesel initially gets decreased up to certain limit, after where it shows a constant value, even though there is an increase in load.

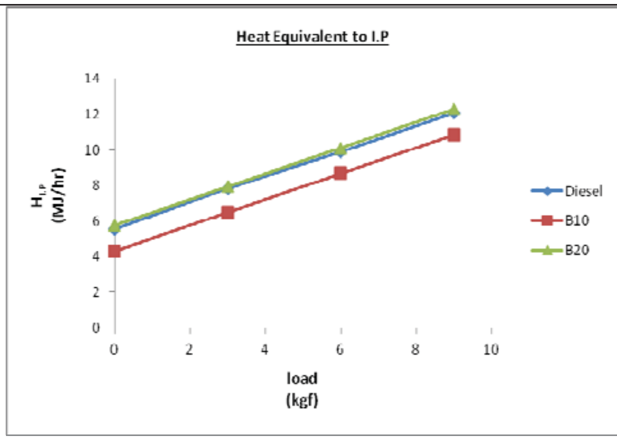
ISFC

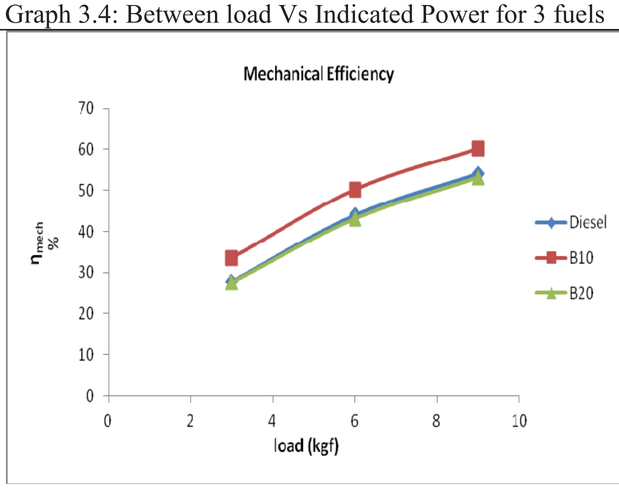


Graph 3.2: Between load Vs I.S.F.C for all three fuels

The above graph shows the variation of Indicated specific fuel consumption for B10, B20 and Diesel almost remains linear with increase in load. However, Diesel is found to have a less value throughout the lap.

<table>
<tr>
<td>H_{full}</td>
<td>

Graph 3.3: Between load Vs Total Heat for all three fuels</td>
<td>The variation of indicated power with increase in load is almost a straight slope. Also, the variation of the fuels with each other is almost constant. This can be assumed to find the further values of indicated power beyond the load condition.</td>
</tr>
<tr>
<td>HI.P</td>
<td>

Graph 3.4: Between load Vs Indicated Power for 3 fuels</td>
<td>From the above graph it has been observed that at any loading condition, the B10 fuel was found to have a higher mechanical efficiency than that of B20 and Diesel. This shows the B10 fuel can give a satisfactory result of mechanical efficiency at any loading conditions.</td>
</tr>
<tr>
<td>η_{mech}</td>
<td>

Graph 3.5: Between load Vs Mechanical Efficiency for all three fuels.</td>
<td>From the above graph it has been observed that the B10 have the high heat producing capacity at higher load, this may be due to the cause of complete combustion of the Bio-Diesel Blend inside the engine cylinder.</td>
</tr>
</table>

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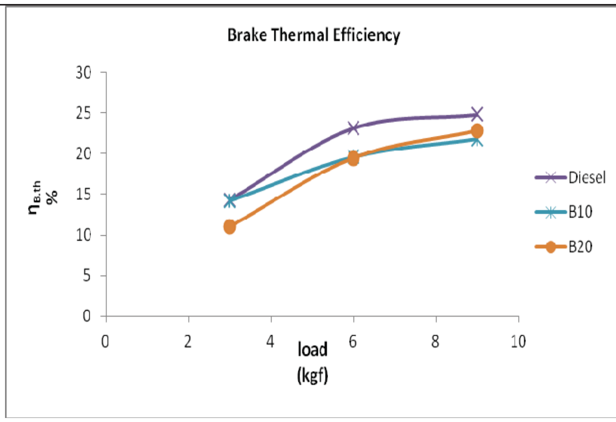
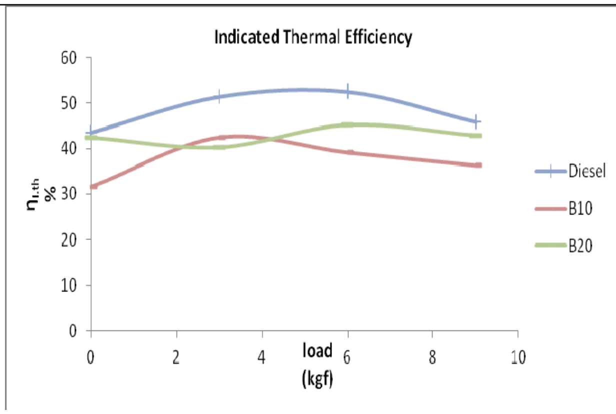
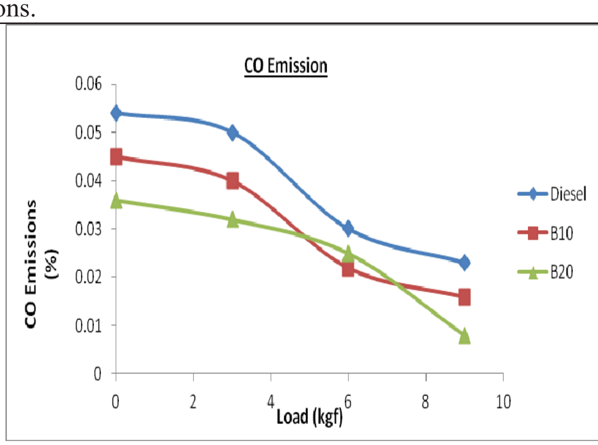
<table>
<tr>
<td>$\eta_{b.th}$</td>
<td>

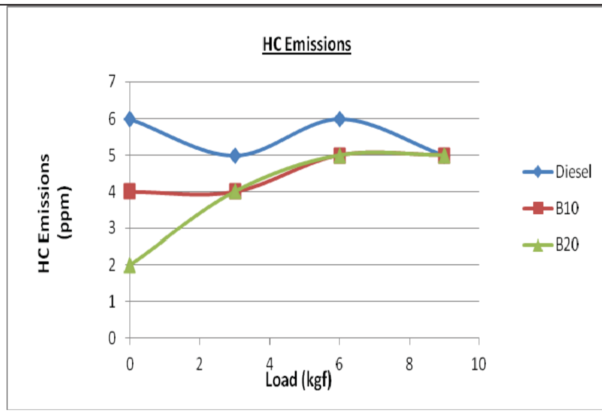
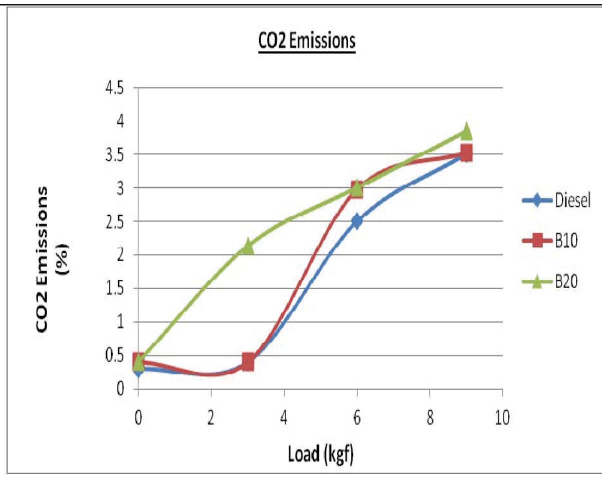
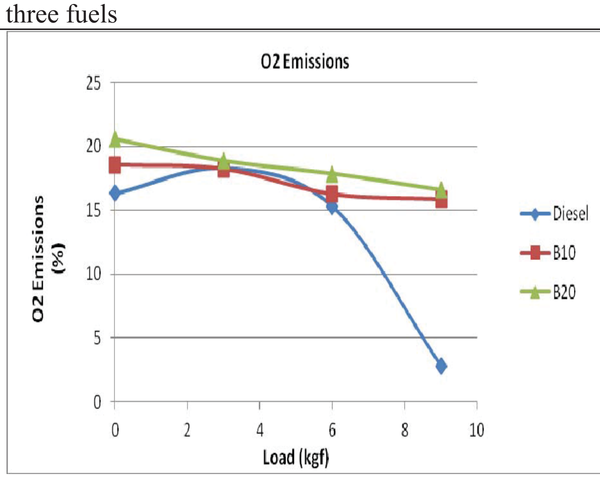
Graph 3.6: Between load Vs Brake Thermal efficiency for all three fuels</td>
<td>From the above graph, it has been observed that the Brake Thermal Efficiency increases for Diesel to certain loads, after which it remains constant. Where as the B20 fuel, keep on increasing with increase in loading.</td>
</tr>
<tr>
<td>$\eta_{I.th}$</td>
<td>

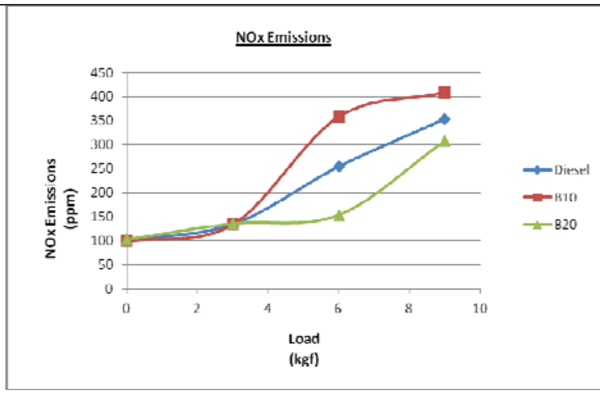
Graph 3.7: Between load Vs Indicated Thermal efficiency for all three fuels</td>
<td>With increase in loading conditions, all the fuels tend to decrease the harmful CO Emissions, however the B20 was found to decrease rapidly under higher loads.</td>
</tr>
</table>

From the Emission results, the following graphs are obtained for diesel, B10 and B20 Bio-fuel Blends under varying load conditions.

<table>
<tr>
<td>CO</td>
<td>

Graph 3.8: Between load Vs CO Emission for all three fuels</td>
<td>Even though the Diesel has a higher value of indicated thermal efficiency at initial loading conditions, it tends decrease on further increase in loads. B10 also shows the similar effect with reduced value. Whereas, the B20 tends to become constant at higher loads.</td>
</tr>
</table>

HC	 Graph 3.9: Between load Vs HC Emission for all three fuels	The above graph shows that the B10 fuel tend to produce a less amount of carbon dioxide emissions at lower loads, but with increase in loads, the value increased drastically.
CO_2	 Graph 3.10: Between load Vs CO2 Emission for all three fuels	The B10 and B20 fuels showed almost no change in the O2 emission within the loading conditions; however the diesel produces a very little value at higher loads.
O_2	 Graph 3.11: Between load Vs O2 Emission for all three fuels	The B10 blend, however shows an increased in NOx emissions, but becomes constant at higher loads. On the other hand, B20 and diesel still tends to increase the NOx emissions.

NOx Emissions	 Graph 3.12: Between load Vs NOx Emission for all three fuels	From the graph it was observed that, all the three fuels showed a huge difference at the starting condition, where as with the increase in load, every fuel tends to produce the same amount of HC.

IV. RESULTS AND CONCLUSION

Results

An experimental analysis was conducted to explore the performance and emission analysis of sunflower oil as fuel blends with diesel in a direct injection single cylinder 4-stroke water cooled diesel engine and the results obtained suggest the following conclusions for increase in load conditions:

- By using the bio-diesel, the engine works smooth, similar to normal diesel engine, without producing any cracking noises.
- The Brake Specific fuel consumption was found to be more in B10 than that of B20 with increase in loading conditions.
- The CO content, which is most harmful gas in the environment is found to be decreasing for B20 with increase in loading.
- The Indicated Specific fuel consumption was also found to be more in B10 blend with increase in loading conditions.
- The total heat generated, H_{full} is maximum for B10 under increase in loading conditions.
- The NO_X is found to be decreasing more for B20 blend than that is petroleum diesel and B10 blend.
- The indicated power is more for B20 fuel than that of petroleum diesel and bio-diesel.
- Under all loading conditions, B10 was found to have the maximum mechanical efficiency, which is necessary for an IC engine.
- With increase in loading condition, the indicated thermal efficiency of B10 has a tendency to show the maximum efficiency than B20.

Conclusions

The B10 was found to be more preferable over diesel and B20 blends, when the mechanical efficiency and brake specific fuel consumption is considered. The B20 blend was preferable when harmful emissions like CO and NOx were necessary to be reduced. The B10 and B20 fuels are preferable when the cost and performances are the factors demanding exclusive from petroleum diesel.

Future Of Bio Diesel

The present research work exhibits the initial feasibility of sunflower oil using B10 and B20 compositions only as a bio-diesel blend for a single cylinder 4-stoke diesel engine. Moreover, the experimental procedure adopted in present research work can be extended to multi-cylinder diesel engines, tractor engines and other diesel engines used in agriculture and transport sector. This research can be carried out for other composition varying from B0 to B100. Also the research can be further continued with other available fuels like Coconut oil, Ground nut oil, Palm oil, Neem oil, Jatropha oil etc.

Acknowledgements

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