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Performance and Emission Test on a CI Engine By using Algae Oil as an Alternative Fuel

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Abstract—Currently the Biggest threat to environment and public health is Air Pollution which is caused by emissions of hydrocarbons, nitrogen oxides, carbon oxides and sulphur oxides by burning of fossil fuels. In recent years consumption of fossil fuels by various factories has rapidly increased that has let for the search of alternative fuels. These fuels are also known as non-conventional fuels which can be used as a substitute for conventional fuels Algae oil is one of the promising potential sources of bio-fuels generated from microbes. It is generally preferred because it is sustainable and environment-friendly oil which have numerous advantages. So the algae oil has used for performance and emission test on a diesel engine. The blends have been made for testing B5, B10. In which 5% of methanol has mixed and others are raw algae oil (5% for B5 and 10% for B10) and Diesel (90% for B5 and 85% for B10). The Kirlosker Engine with 6.97 HP (5.2KW)@1500rpm is used for Performance analyzing. Parallels AVL emission analyzer and smoke detector were connected with the exhaust of the engine. All values of gases were displayed and compared.

Keyword- Biodiesel, algae oil, Methanol, performance and Emission Characteristics

I. INTRODUCTION

Now a days the demand of the fossil fuel is very high because the increase in the number of the vehicles. The research on the biodiesel as an alternative fuel is continuously increasing. Biodiesel is one of the renewable fuels and it emits very less amount of carbon dioxide (CO_2) and carbon monoxide (CO) and high amounts of nitrogen oxides (NOx). It can be effectively used in compression ignition engine. The biodiesels are from the animal's fats and plants like algae, neem, soybean, safflower, jatrophacurcas, common flower, camelina sativa and its effect reduces in the exhaust emission system in CI engine. Biofuels are liquid fuels made from esters, alcohols, and other biomass chemicals.

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II. PROCEDURE

A. *Algae oil extraction:*

Algae naturally produced oil as away to store chemical energy. Small numbers of algae are then put into a tank with water and nutrients similar to those in thousands of fertilizers. Algae is then kept under the sunlight then it rapidly reproduces and undergoes photosynthesis, converting carbon dioxide into sugar into lipids or oil, cell cavity fills with as much as six percent of its weight in oil. Some companies press the algae like olive, physically squeezing the oil out. Other companies compress the carbon dioxide which vaporizes the lipid until the press is lower and the oil condensed from the remaining cell. Then the oil is stored in isolated cylindrical metal bottles.

Table-I: Properties of extracted Algae oil

S.no.	Parameter	Value	Unit
1	Density at 30^0	0.9042	gm/ml
2	Viscosity at 40^0	35.76	cst
3	Specific gravity	0.9116	-
4	Gross calorific value	9272	kcal/Kg
5	Flash point	318	^{0}C
6	Fire point	328	^{0}C

B. *Preparation of blends:*

The Viscosity of Algae Oil is too high to be mixed with diesel. The spark ignition won't work with high viscous Blends. So to decrease high viscosity of algae oil, a catalyst has been used named as Methanol(CH_3OH). The methanol is highly flammable and it is having flash point of 12^0 C. The methanol is also having low viscosity which is around 0.6906 CST at 25.0^0C. And it's never been used with Algae oil before for performance test. So four blend were prepared for the Viscosity test and flash and fire point test.

B5 = 100ml Algae oil and 5ml Methanol
B10 = 100ml Algae oil and 10ml Methanol
B15 = 100ml Algae oil and 15ml Methanol
B20 = 100ml Algae oil and 20ml Methanol

All these blends are going to be tested for viscosity test and flash and fire point so that we can find out whether there properties get along with the CI engine.

The conditions are:

The flash and fire point should be under 90^0C and Viscosity should be less than 8 CentiStokes.

C. *Viscosity Test:*

For viscosity test Redwood and Say bolt viscometers used.

The comparison has done between them with comparing a single blends curve. In final comparison result, Redwood is having more accurate values and curve than the Say bolt equipment. So other blends were calculated on Redwood equipment.

Table II: Say bolt reading

SAYBOLT B5				
TEMPERATURE OF OIL	TIME	KINEMATIC VISCOSITY	DENSITY	ABSOLUTE VISCOSITY
^{0}C.	SEC.	M^2/Sec.	Kg/Lit	M^2/Sec.
67	128	30.942	0.64	19.761
72	123	29.704	0.608	17.972
77	118	28.595	0.575	16.409

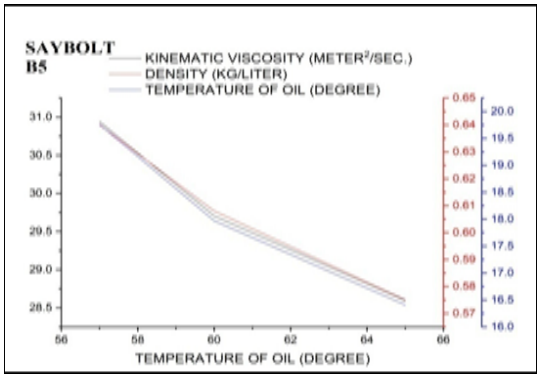

Figure 1: Saybolt Viscosity graph for blend B5

Table-III: Redwood B5 reading

REDWOOD B5				
TEMPERATURE OF OIL	TIME	KINEMATIC VISCOSITY	DENSITY	ABSOLUTE VISCOSITY
^{0}C.	SEC.	M^2/Sec.	Kg/Lit	M^2/Sec.
67	127	30.857	0.64	19.761
72	122	29.601	0.607	17.972
77	118	28.595	0.574	16.409
80	116	28.092	0.553	15.559

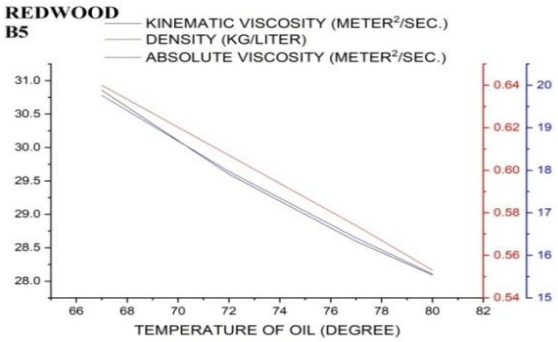

Figure 2: Redwood viscosity graph for blend B5

Table IV: Redwood B10 reading

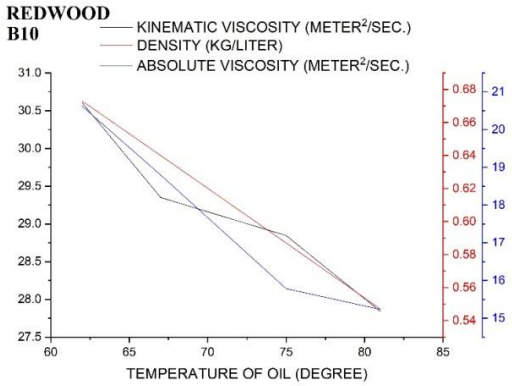

Figure 3: Redwood viscosity graph for blend B10

Table V:Redwood B15 reading

REDWOOD B15				
TEMPERATURE OF OIL	TIME	KINEMATIC VISCOSITY	DENSITY	ABSOLUTE VISCOSITY
^{0}C.	SEC.	M^2/Sec.	Kg/Lit	M^2/Sec.
61	124	30.104	0.68	20.481
67	122	29.601	0.64	18.957
74	120	29.098	0.593	17.279
81	116	28.092	0.547	15.372

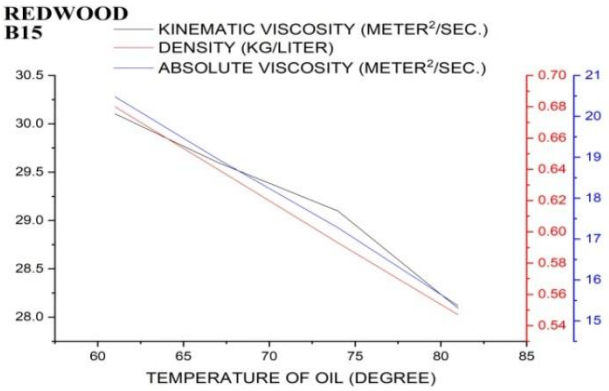

Figure 4: Redwood viscosity graph for blend B15

Table VI: Redwood B20 reading

REDWOOD B20				
TEMPERATURE OF OIL	TIME	KINEMATIC VISCOSITY	DENSITY	TEMPERATURE OF OIL
^{0}C.	SEC.	M^2/Sec.	Kg/Lit	M^2/Sec.
62	124	30.104	0.674	20.281
65	120	29.098	0.653	19.022
75	118	28.595	0.587	16.79
82	114	27.588	0.541	14.913

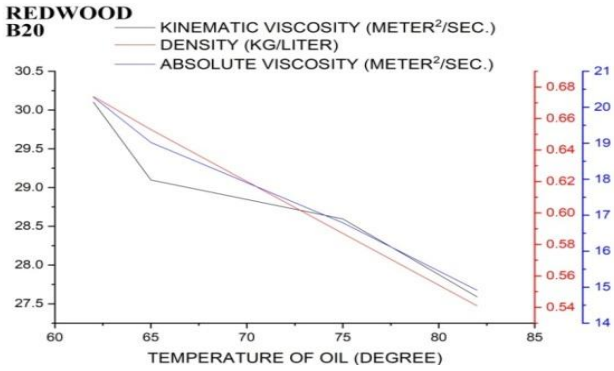

Figure 5 Redwood viscosity graph for blend B20

The readings are not in accordance with the given viscosity condition . So the flash and fire point test was conducted for the blends to check the condition.

C. Flash and Fire Point Test:

The close cup apparatus has been used for flash point and fire point. Because it gives the minimum value of flash and fire point and works better then the Open cup apparatus. So, the results of the closed cup apparatus are:

Table VII: Flash, fire point of B5

Table VIII: Flash, fire of B10

CLOSE CUP FOR B5		CLOSE CUP FOR B10	
FLASH POINT	FIRE POINT	FLASH POINT	FIRE POINT
^{0}C.	^{0}C.	^{0}C.	^{0}C.
240	266	237	257

Table IX: Flash & fire point of B15

CLOSE CUP FOR B15	
FLASH POINT	FIRE POINT
^{0}C.	^{0}C.
235	256

Table IX: Flash & fire point of B20

CLOSE CUP FOR B20	
FLASH POINT	FIRE POINT
^{0}C.	^{0}C.
231	249

Even these flash and fire point readings were not in accordance with the expected conditions.

So the final ratio of algae oil, Methanol and Diesel should be less than 2:1:17.

D. Final Blends Preparation:

For the final blends the expected ratio should be under 2:1:17. So there are 2 types of blends:

5% Algae oil + 5% Methanol + 90% Diesel

10% Algae oil + 5% Methanol + 85% Diesel

The blend were prepared for performance and emission test. There are two types of blends with new names are there

Blend B5 = Algae oil 5% + Methanol 5% + Diesel 90% = **A5M5D90**

Blend B10 = Algae oil 10% + Methanol 5% + Diesel 85% = **A10M5D85**

Before making the blends, Properties were found for pure algae oil. Then the oil was mixed in a beaker with Methanol and diesel with above given ratios. Then the magnetic stirrer was done on the both blends and contained them in a isolated container.

For performance test the engine is selected as per the following properties:

Make: Kirloskar

No. Of cylinders: 1

No. Of strokes: 4

Fuel type: diesel

Related Power: 6.97HP(5.2KW) @1500rpm

The blend B5 filled into the engine's fuel tank and Engine's all connections were checked including AVL Exhaust gases analyser and Smoke detector. The Engine started manually. The load was give gradually and output was taken as per the load. The same was done for B10 blend. After putting each load on the engine, the pipe of AVL exhaust analyzer is tuck in the exhaust of engine and removes it after getting readings. Then smoke detectors pipe is tuck in for the total smoke in ppm value from the exhaust. All the values were directly calculated by the computer.

The final tables for blends are:

Table XI: Blend B5 performance

Blend B5 Performance			
LOAD(kg)	**IP(KW)**	**BP(KW)**	**FP(KW)**
0	4.61	-0.06	4.66
4	6.04	1.15	4.96
8	6.11	2.29	3.75
12	6.63	3.36	3.27
16	7.06	4.39	2.67

Table XII: Blend B5 performance

Blend B5 Performance				
IThEff (%)	BThEff (%)	SFC (kg/kWh)	Mech Eff (%)	VolEff (%)
83.72	-1.05	0	-1.25	75.02
69.38	13.08	0.63	18.85	74.51
52.25	19.8	0.41	37.9	73.75
44.64	22.6	0.36	50.63	73.71
35.66	22.18	0.37	62.2	72.77

Table XIII: Blend B10 performance

Emissions for Blend B10								
Load	Time sec.	Manometer reading	CO	HC	CO_2	O_2	NO_X	Smoke
kg	Sec.	Sec. for per 10cc oil	%	%	%	%	%	%
0	71.48	68	0.03	9	1.6	18.45	85	24.6
4	39.08	65	0.03	12	3.1	16.31	290	31.2
8	29.58	63	0.03	17	4.7	14.17	510	35.4
12	23.92	60	0.03	21	5.8	12.48	637	36.9
16	17.53	57	0.52	23	4.7	13.52	345	100

Table XIV: Blend B10 performance

Blend B10 Performance			
LOAD (kg)	IP (KW)	BP (KW)	FP (KW)
0	4.7	0	4.62
4.01	6.4	1.05	4.35
8.03	6.2	2.01	4.19
12	7.2	3.04	3.8
16.02	7.8	4.05	3.75

E. Emission Test:

The exhaust gases passes through the AVL Exhaust analyzer and smoke detector. All gases are calculated in % and smoke is calculated in ppm. So the output has been tabulated:

Table XV: Emission for blend B5

Blend B10 Performance				
IThEff (%)	BThEff (%)	SFC (kg/kWh)	MechEff (%)	VolEff (%)
85.75	0	0	0	77.04
70.2	12.04	0.64	16.41	76.26

54.1	18.04	0.43	32.41	74.38
45.76	21.3	0.36	42.22	73.98
36.89	20.89	0.38	51.92	70.76

TABLE XVI: Emission For Blend B10

Emissions for Blend B5								
B5	B5	B5	B5	B5	B5	B5	B5	B5
Load	Time sec.	Manometer reading	CO	HC	CO_2	O_2	NO_X	Smoke
Kg	**Sec.**	**Sec. for per 10cc oil**	**%**	**%**	**%**	**%**	**%**	**%**
0	64.2	69	0.02	6	1.1	19.51	59	20.1
4	36	65	0.02	9	2.1	17.93	226	29.1
8	29.6	62	0.02	11	2.5	17.93	465	34.5
12	32.3	60	0.02	13	2.4	17.68	570	53.6
16	17	57	0.35	22	2	17.96	303	94.8

III. RESULT

A. For performance:

After doing performance test and emission analysis of two blends, the comparison is done between both the blends and diesel. Here's the result:

In load vs Indicated power, brake power and frictional power, the garph shows the perfomance of Diesel and Blend B5 are similare or almost same but B10 is far from Diesel properties as compare to B5.The graphical comarison is given below

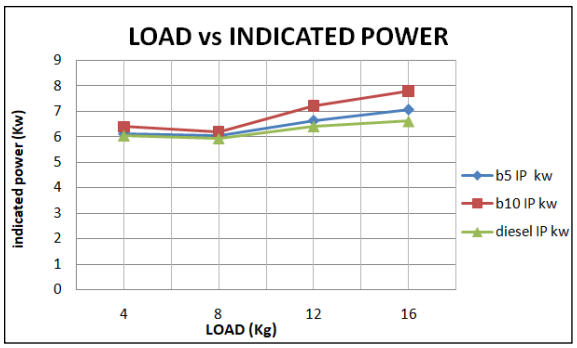

Figure 6: Graph Load vs Indicater Power

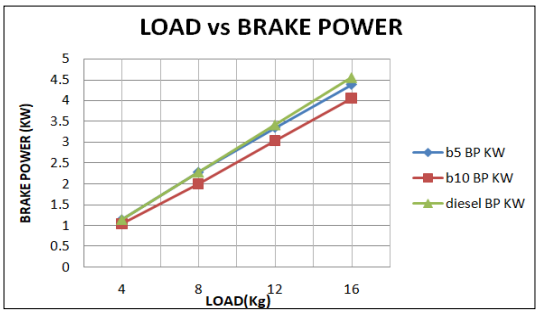

Figure 7: Graph Load vs Brake power

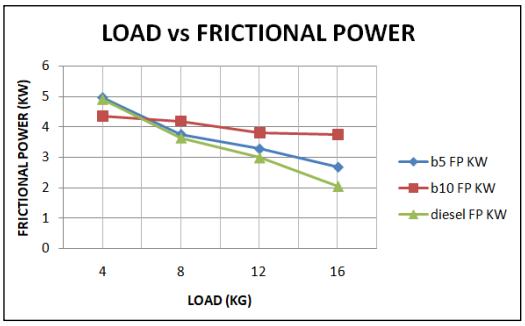

Figure 8: Graph Load vs Frictional Power

In load vs Indicated thermal efficiency & Brake thermal efficiency, the garph shows the perfomance of Diesel and Blend B5 are similare or almost same but B10 is far from Diesel properties as compare to B5.The graphical comarison is given below:

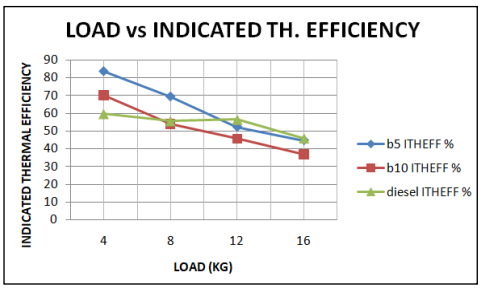

Figure 9: Graph Load vs Indicater Thermal Efficiency

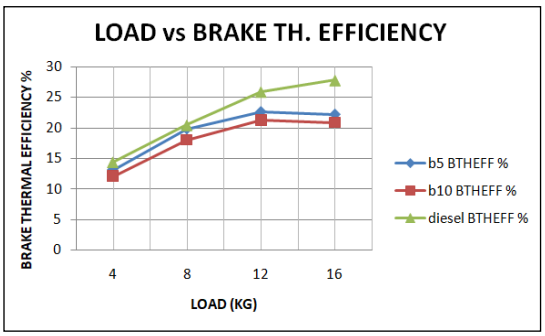

Figure 10: Graph Load vs Break Thermal Efficiency

In load vs Spacific fuel consumption and mechanical efficiency, the garph shows the perfomance of Diesel and Blend B5 are similare or almost same but B10 is far from Diesel properties as compare to B5.The graphical comarison is given below

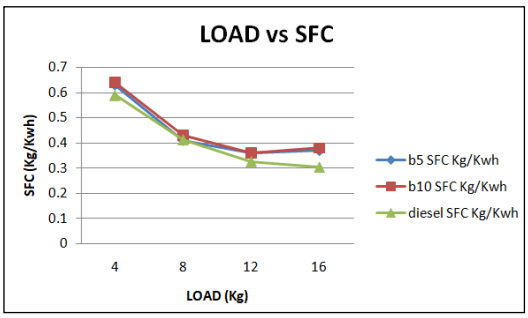

Figure 11: Graph Load vs SFC

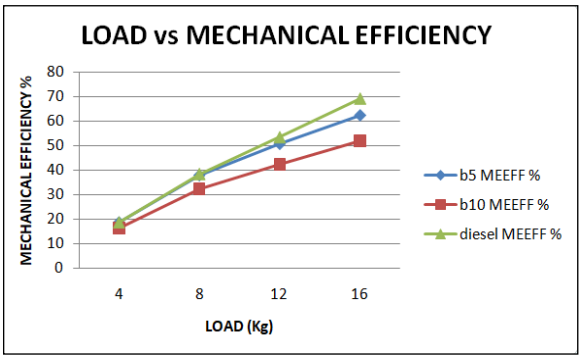

Figure 12: Graph Load vs Mechanical efficiency

B. For emission:

The exhaust output has been analysed between different blends and fuel with respect to single component or gas or output matter. In exhaust the B10 has the bad result and are not even close to diesel's output results. But B5 has given a good output than compare to diesel. Carbon monoxide has given a quite similar for both diesel and B5. But the hydrocarbons are less for B5 than the diesel which is a positive output.

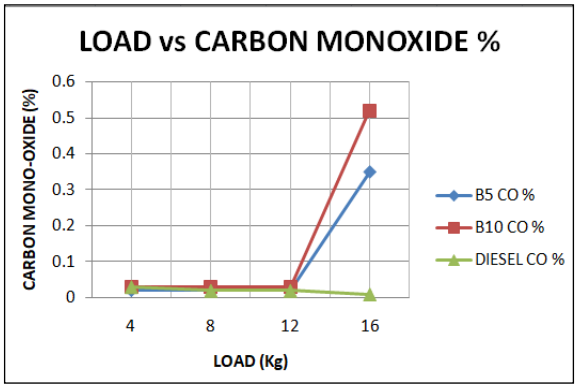

Figure 13: Graph Load vs Carbon monoxide

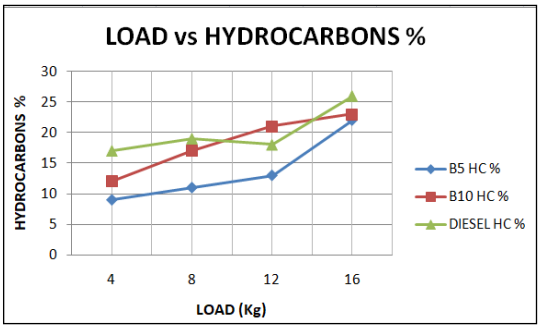

Figure 14: Graph Load vs Hydrocarbon

The comparison between b5 and diesel for carbon dioxide is similar. But still B5 emits less carbon dioxide. The comparison between b5 and diesel for oxygen is similar. But still B5 emits more oxygen which is good for environment.

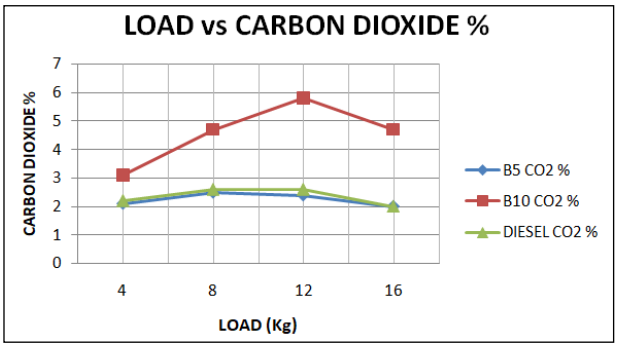

Figure 15: Graph Load vs Carbon dioxide

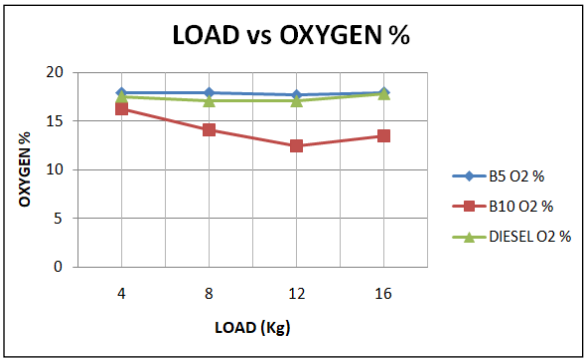

Figure 16: Graph Load vs Oxygen

The result for NOx is totally different. Because Diesel has the lower emission of NOx, but B5 and B10 has similar and high emission of NOx.

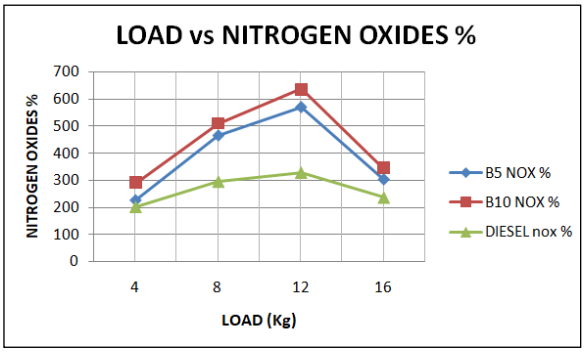

Figure 17: Graph Load vs Nitrogen oxide

So for emission test, only NOx comparison failed. Others gases and matter are better in B5 then the diesel. B10 completely failed the test.

IV. CONCLUSION

The B5 blend turned out to have a significantly lower emission rate than the diesel which makes it a much better option in today's era where increasing pollution is a world-wide concern. The performance of diesel was marginally better than that of the B5 blend. So, considering B5 blend's much lower emission rate but a marginally lesser performance index than the diesel, a better trade off will be in case of using B5 blend over conventional diesel. Taking the world-wide rising pollution into consideration, the emission rate is a bigger concern and hence B5 is suited to replace diesel. Further improvements upon the B5 blend can, in future, help it to surpass the performance level of the diesel.

In case of B10 blend, due to increase in the quantity of the algae oil, it caused a decline in performance index. Hence it can also be concluded the quantity of algae oil has to be just right, that is, it can neither be too high nor too low, for optimum performance and B5 blend proved to have the apt quantity of algae oil.

The catalyst used with both B5 and B10 blends was methanol. The use of a better catalyst in future may help in improving the performance of B10 blend, enabling us to use more and more organic algae oil instead of the non-renewable diesel.

REFERENCES

1. J. Kuberan, N. Alagumurthi, (2016) "Performance and Emission Characteristics of Algae Bio-fuelled Diesel Engine", Int J. Chem. Sci.: 14(4), 2973-2980, ISSN 0972-768X,
2. Ramón Piloto-Rodrígueza, Yisel Sánchez-Borrotoa, Eliezer Ahmed Melo-Espinosaa, Sebastian Verhelstb, (2016) "Assessment of diesel engine performance when fueled with biodiesel from algae and microalgae", 1364-0321, Elsevier Ltd.,
3. Panayiotis Tsaousisa, YaodongWanga, Anthony P.Roskillya, Gary S. Caldwellb, (2014) "Algae to energy: Engine performance using raw algal oil", The 6th International Conference on Applied Energy – ICAE2014
4. RachanKarmakar, KrishnenduKundu, Anita Rajor, (2018) "Fuel properties and emission characteristics of biodiesel produced from unused algae grown in India", Petroleum Science (2018) 15:385-395, Spriger
5. Jitesh Singh Patel, Naveen Kumar, Amar Deep, Abhishek Sharma, Dhruv Gupta, (2014)"Evaluation of Emission Characteristics of Blend of Algae Oil Methyl Ester with Diesel in a Medium Capacity Diesel Engine," SAE Technical Paper 2014-01-1378, doi:10.4271/2014-01-1378
6. Ashokkumar A, Vishnu Padmanaban, and ThirumaliniSubramaniam,(2013) "A Comparison of Fuel Properties Between Fractionated and Non-Fractionated Composition of Micro Algae Based Biodiesel", 2013-01-2814, SAE International
7. G. Ospina, Mohamed Y.E. Selim, Salah A.B. Omari, Mohamed I. Hassan Ali, Adel M.M. Hussien (2018), "Engine roughness and exhaust emissions of a diesel engine fuelled with three biofuels", 0960-1481, Elsevier Ltd.,https://linkinghub.elsevier.com/retrieve/pii/S0960148118311091
8. R. Velappan, S. Sivaprakasam, M. Kannan (2015), "Study the Performance of Algae Oil in Diesel Engine with Various Injection Pressure",International Research Journal of Engineering and Technology(IRJET), Volume: 02 Issue: 05

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