PERFORMANCE AND EMISSION ANALYSIS OF DIESEL ENGINE USING DELONIX REGIA OIL WITH DIESEL BLENDS

Solomon durairaj

Assistant Professor, Dept. of Mechanical Engineering, CK College of Engineering & Technology, Tamilnadu, India

---***---

ABSTRACT - Due to the increasing awareness of the depletion of fossil fuel resources and environmental issues, biodiesel became more and more attractive in the recent years. Biodiesel production is a promising and important field of research because it arises from the rising petroleum price and its environmental advantages. Many studies have shown that the properties of biodiesel are very close to those of diesel fuel.

In this study, the combustion, performance and emission characteristics of conventional diesel fuel and biodiesel produced from delonix regia oil and its blends (B25, B50, B75 and B100) were compared. The tests were performed at steady-state conditions in a single-cylinder direct injection diesel engine over the entire rpm range (1500 rpm). During the tests, the fuel consumption, pollutant emissions, exhaust temperature and in - cylinder pressures were measured. The experimental results shows that biodiesel had increase in the specific fuel consumption (SFC) is increased at higher brake power and also brake thermal efficiency is increased by 2.5% on B25. However, biodiesel significantly reduce the nitric oxides (NOx) and carbon dioxide (CO2) emissions slightly, while increase in carbon monoxide (CO), unburned total hydrocarbons takes place. The combustion analyses showed that the addition of biodiesel to conventional diesel fuel decreased the ignition delay and reduced the premixed peak. These results indicated that biodiesel could be used without any engine modifications as an alternative and environmentally friendly fuel.

Keywords: Ignition, Emission, Biodiesel, Peak, Hydrocarbon

1. INTRODUCTION

India is home to 1.2 billion people, who are about, 17% of world population, and its thirst for energy is unquenchable. One harsh result of its meteoric growth is the widening gap between the energy produced and energy required by the country. On an average India produces about 8,26,000 barrels of oil per day and requires about 3,319,000 barrels of oil per day (2010) (statistical review of world energy, 2011). Further, with the growth of human population and industrialization there will steadily increase in energy demand. Major sources of energy are petroleum, coal, and natural gas which are nonrenewable source of energy. Due to the increasing demand of energy all over the world had lead to depletion of non-renewable source of energy. Biodiesel does not contain petroleum, but petroleum can be mixed to produce a biodiesel blend (e.g. B20, B50) that can be used in many different vehicles. Pure biodiesel fuel (i.e. B100) though, can only be used in diesel engines. Biodiesel is biodegradable and non-toxic, making it so safe that it is even safer than the commonly used table salt.

1.1 Biodiesel

Biodiesel is defined as a fuel comprised of mono alkylesters of long chain fatty acids derived from vegetable oils or animal fats. It can be directly used in the compression ignition engine. Biodiesel fuel is a clean burning alternative fuel that comes from 100% renewable resources. Many people believe that the biodiesel is the fuel of the future. Sometimes it is also known as biofuel. Biodiesel does not contain petroleum, but petroleum can be mixed to produce a biodiesel blend i.e. B20 (20% biodiesel and 80% petroleum), B50 (50% biodiesel and 50% petroleum) that can be used in many different automobiles. Pure biodiesel fuel B100 though, can only be used in diesel engines. Biodiesel is biodegradable and nontoxic, making it so safe that it is even safer than the commonly used table salt. Biodiesel can be used in its unaltered form in diesel engines must be modified and used only in combustion-ignition engines.

2.1 LITERATURE REVIEW

Sulakshana S. Deshpande et al (2017) discussed about the blends of biodiesel with small content in place of petroleum diesel can help in controlling air pollution and easing the pressure on scarce resources without significantly sacrificing engine power and economy. However, many further researches about optimization and modification on engine, low temperature performances of engine, new instrumentation and methodology for measurements, etc., It should be performed when petroleum diesel is substituted completely by biodiesel.

R.Sunilkumar et al (2016) Investigated the exhaust gas temperature increases linearly with load and is highest for pure biodiesel. The engine emission analysis with the above test fuels show that CO, CO2, HC and smoke emissions increase with load for all test fuels. The NOx emission increases with load and is highest for pure biodiesel. From the results obtained during the ongoing experimental investigation it may be concluded that the karanja oil methyl ester blends with diesel can be successfully used in a compression ignition engine without degrading the engine performance and emission.

M. A. Ibrahim et al (2015) Experimented By using Karanja oil methyl ester blends with diesel fuel, the result showed that the brake thermal efficiency of biodiesel blends with diesel fuel we less as compared to diesel fuel. Fuel consumption was increased with increase in blend proportions. It is found that the emission level of CO and HC level decreased with increased in blend proportion in diesel fuel. NOx emission increased with increase in blend proportion in diesel fuel.

2.2 REASON FOR SELECTING DELONIX REGIA

- Availability of delonix regia is abundant in all over the world,
- The wood is employed locally for agriculture implements; handles for carpentary tools, combs etc.
- Principle use is a fuel, the calorific value of wood being 4600 kcal/kg.
- The tree is mainly valued for its seeds, leaves, shade and ornamental value.
- The tree is mainly grown for its shade and ormental value. Because of its hardy nature and aggressive root system, it is a good tree to control soil erosion in the arid and semi-arid areas.

Figure 2.1 Delonix regia **in** Tree

3. EXPERIMENTAL SETUP

Experiments were conducted in a Kirloskar Diesel Engine and the speed of the engine was kept almost constant at 1500 rpm and the load on the engine is given by 20%, 40%, 60%, 80% and 100%. First the compression ratio of the engine was kept as 14 to 18 and then the blends of Delonix regia oil B25, B50, B75, and B100 were used as fuel in engine. Methods and compared with diesel properties. The figure 4.1 shows the experimental setup.

The experiments were conducted on a stationary single cylinder four stroke air cooled diesel engine with electrical loading and the performance and emission characteristics were compared with baseline data of diesel fuel.

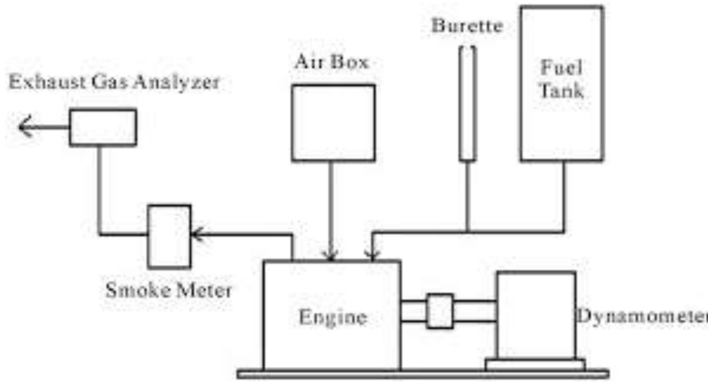

Figure 3.1 Experimental setup

Tests were conducted at a constant speed and at varying loads for all dual biodiesel blends. Engine speed was maintained at 1500 rpm (rated speed) during all experiments. Fuel consumption and exhaust gas temperatures were also measured. The exhaust emissions were measured by Di-gas analyzer. The digital bomb calorimeter is used to find out the calorific value of fuels.

4. EXPERIMENTAL OBSERVATION

The precautions to be followed before starting the engine such as the lubricating oil, air lock (if any in the fuel line) cooling water, supply, no load condition and fuel level were checked. The speed of the engine and the rate of fuel consumption were monitored at every stage. The inlet and outlet temperature of cooling water was noted for every load. The exhaust gas temperature was also observed at various loads. The engine was sufficiently warmed at every stage. The test setup is shown in various figures. At each load brake thermal efficiency can be evaluated from brake power.

4.1VARIOUS LOAD TEST

Load test will be conducted on the 5HP engine for the following fuels of biodiesel,

1. with pure high speed diesel.
2. With B25% preheated delonix regia oil blended diesel.
3. With B50% preheated delonix regia oil blended diesel.
4. With B75% preheated delonix regia oil blended diesel.
5. With B100% preheated delonix regia oil blended diesel.

4.1.1 LOAD TEST OF DIESEL

The following observation is recorded by load test standard Diesel, and the details are shown in table 4.1

Table 4.1 load test of diesel

% load	Calculated load	Time taken for 10cc of fuel consumptions			EGT	Smoke density	CO	HC	NO_X
	N	T1 (sec)	T2 (sec)	Tavg (sec)	^0C	HSU	% by volume	ppm	ppm
20	33.354	43.00	43.10	43.05	180	20.3	0.05	17	427
40	67.689	39.80	39.74	39.77	224	37.6	0.07	35	547
60	101.043	30.16	30.37	30.26	257	52.0	0.07	47	740
80	135.378	25.03	25.07	25.05	310	60.1	0.09	65	947
100	169.713	22.12	22.14	22.13	350	65.8	0.24	67	1210

Table 4.2 Calculated results (diesel)

% of load	Brake Power	Total Fuel Consumption	Specific Fuel Consumption	Indicated power	Brake thermal efficiency	Mechanical efficiency
	KW	Kg/hr	KW/Kg-hr	KW	%	%
20	1.0216	0.6898	o.6673	2.2716	12.39	44.97
40	2.0733	0.7467	0.3601	3.3235	23.24	62.38
60	3.0950	0.9814	0.3170	4.345	26.40	71.26
80	4.1445	1.1854	0.2859	5.3965	29.28	76.83
100	5.1985	1.3420	0.2581	6.4483	32.43	80.61

4.1.2 LOAD TEST OF DIESEL WITH B25

Table 4.3 load test of Diesel with B25

% of load	Calculated load	Time taken for 10cc of fuel consumptions			EGT	Smoke density	CO	HC	NOX
	N	T1 (sec)	T2 (sec)	Tavg (sec)	0C	HSU	% by volume	ppm	ppm
20	33.354	40.2	40.12	40.16	185	26.8	0.05	12	320
40	67.689	39.08	39.08	39.08	225	48.1	0.06	26	540
60	101.043	28.16	28.17	28.16	257	59.6	0.09	38	721
80	135.378	22.10	22.16	22.13	311	67.0	0.09	49	911
100	169.713	21.11	21.13	21.12	324	78.3	0.24	57	1124

Table 4.4 Calculated results (B25)

% of load	Brake Power	Total Fuel Consumption	Specific Fuel Consumption	Indicated power	Brake thermal efficiency	Mechanical efficiency
	KW	Kg/hr	KW/Kg-hr	KW	%	%
20	1.0216	0.748	0.7321	2.4216	11.70	42.18
40	2.0733	0.769	0.3709	3.4733	23.10	59.69
60	3.0950	1.0674	0.3448	4.495	24.85	68.85
80	4.1466	1.3583	0.3275	5.5466	26.16	74.75
100	5.1983	1.4232	0.2737	6.5983	31.30	78.78

4.1.3 LOAD TEST OF DIESEL WITH B50

Table 4.5 load test of Diesel with B50

% of load	Calculated load	Time taken for 10cc of fuel consumptions			EGT	Smoke density	CO	HC	NOX
	N	T1 (sec)	T2 (sec)	Tavg (sec)	0C	HSU	% by Volume	ppm	Ppm
20	33.354	32.37	32.27	32.32	190	36.0	0.09	18	286
40	67.689	29.00	29.20	29.1	250	58.3	0.08	24	510
60	101.043	27.25	27.20	27.225	263	69.8	0.08	53	624
80	135.378	21.19	21.20	21.195	301	76.3	0.09	67	864
100	169.713	17.15	17.20	17.175	326	83.1	0.24	76	984

Table 4.6 Calculated results (B50)

% of load	Brake Power	Total Fuel Consumption	Specific Fuel Consumption	Indicated power	Brake thermal efficiency	Mechanical efficiency
	KW	Kg/hr	KW/Kg-hr	KW	%	%
20	1.0216	0.9356	0.9158	3.1216	9.53	32.72
40	2.0733	1.0391	0.5011	4.1733	17.42	49.68
60	3.0950	1.1109	0.3589	5.195	24.32	59.57
80	4.1466	1.4270	0.3441	6.2466	25.37	66.38
100	5.1983	1.7612	0.3388	7.2983	25.77	71.22

4.1.4 LOAD TEST OF DIESEL WITH B75

Table 4.7 load test of Diesel with B75

% of load	Calculated load	Time taken for 10cc of fuel consumptions			EGT	Smoke density	CO	HC	NOX
	N	T1 (sec)	T2 (sec)	Tavg (sec)	0C	HSU	% by Volume	Ppm	ppm
20	33.354	30.25	30.20	30.225	195	43.7	0.09	21	231
40	67.689	27.72	27.15	27.435	236	68.0	0.09	36	476
60	101.043	21.13	21.22	22.675	291	79.3	0.08	57	641
80	135.378	21.12	21.16	21.14	296	82.3	0.08	61	816
100	169.713	16.47	16.40	16.735	316	85.7	0.31	74	918

Table 4.8 Calculated results (B75)

% of load	Brake Power	Total Fuel Consumption	Specific Fuel Consumption	Indicated power	Brake thermal efficiency	Mechanical efficiency
	KW	Kg/hr	KW/Kg-hr	KW	%	%
20	1.0216	1.0183	0.9967	3.1616	8.879	32.72
40	2.0733	1.1219	0.5411	4.2133	16.35	49.20
60	3.0950	1.3574	0.4385	5.2350	20.18	59.12
80	4.1466	1.4560	0.3511	6.2866	25.20	65.94
100	5.1983	1.8728	0.3602	7.3383	24.57	70.83

4.1.5 LOAD TEST OF DIESEL WITH B100

Table 4.9 load test of Diesel with B100

% of load	Calculated load	Time taken for 10cc of fuel consumptions			EGT	Smoke density	CO	HC	NOX
	N	T1 (sec)	T2 (sec)	Tavg (sec)	0C	HSU	% by Volume	Ppm	ppm
20	33.35	36.12	36.12	36.12	185	52.3	0.09	20	271
40	67.68	29.11	28.27	28.79	226	68.1	0.09	29	390
60	101.04	24.09	24.10	24.09	261	89.0	0.10	36	621
80	135.37	19.55	19.50	19.52	299	90.4	0.16	41	729
100	169.71	16.03	16.05	16.04	310	91.5	0.17	55	763

Table 4.10 Calculated results (B100)

% of load	Brake Power	Total Fuel Consumption	Specific Fuel Consumption	Indicated power	Brake thermal efficiency	Mechanical efficiency
	KW	Kg/hr	KW/Kg-hr	KW	%	%
20	1.0216	0.8571	0.8388	4.0016	10.75	25.52
40	2.0733	1.0791	0.5204	5.0533	17.33	41.02
60	3.0950	0.6424	0.2075	6.075	43.46	50.94
80	4.1466	1.5856	0.3823	7.1266	23.59	58.18
100	5.1983	1.9301	0.3712	8.1783	24.30	63.56

5. PERFORMANCE & EMISSION ANALYSIS

Performance analysis includes total fuel consumption, specific fuel consumption, Brake thermal efficiency, Exhaust gas temperature and Emission analysis includes Nitrogen oxide, Carbon monoxide, Hydrocarbon, Smoke density.

5.1 Total Fuel Consumption

The results of total fuel consumption (kg\hr) of various brake power with different blends for the performance and emission analysis of diesel engine using delonix regia oil with diesel blends are shown in Table 5.1.

Table 5.1 Results of Total Fuel Consumption with various blends

BRAKE POWER (KW)	DIESEL (Kg/hr)	B25 (Kg/hr)	B50 (Kg/hr)	B75 (Kg/hr)	B100 (Kg/hr)
1.0216	0.6898	0.748	0.9356	1.0183	0.8571
2.0733	0.7467	0.877	1.0391	1.1219	1.0791
3.0950	0.9814	1.1245	1.1109	1.3574	1.6424
4.1465	1.1856	1.3312	1.4270	1.4560	1.5856
5.1985	1.3420	1.4362	1.7612	1.8728	1.9301

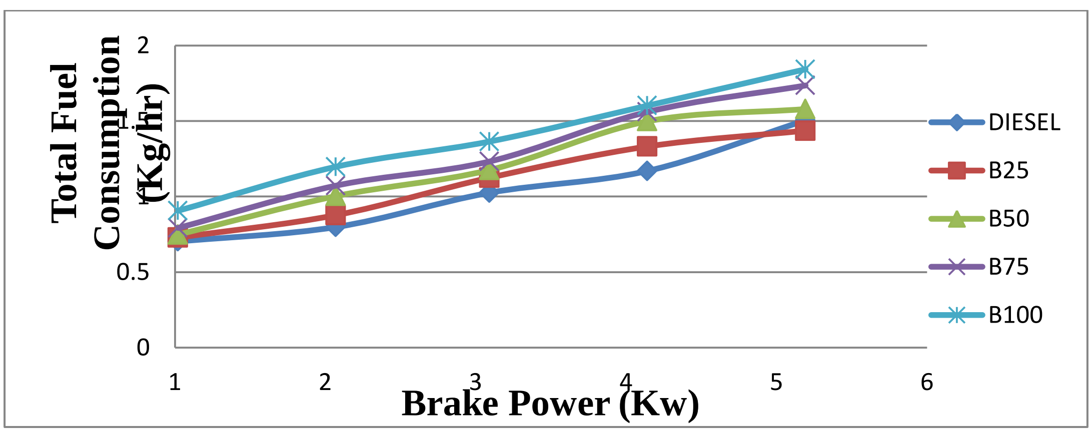

Figure 5.1 Results of Total Fuel Consumption with various blends

It is noted from the graph TFC is higher than that of diesel at all loads this is because of low calorific values of delonix regia biodiesel and its blends as compared to diesel which is shown in Figure 5.1.

5.2 Specific Fuel Consumption

The results of specific fuel consumption (kw/kg-hr) various loads with different blends are shown Table 5.2.

Table 5.2 Results of Specific Fuel consumption with various Blends

BRAKE POWER KW	DIESEL (Kw/kg-hr)	B25 (Kw/kg-hr)	B50 (Kw/kg-hr)	B75 (Kw/kg-hr)	B100 (Kw/kg-hr)
1.0216	0.6673	0.7321	0.9158	0.9967	0.8388
2.0733	0.3601	0.3709	0.5011	0.5411	0.5204
3.0950	0.3170	0.3448	0.3589	0.4385	0.2075
4.1465	0.2859	0.3275	0.3441	0.3511	0.3823
5.1985	0.2581	0.2737	0.3388	0.3602	0.3712

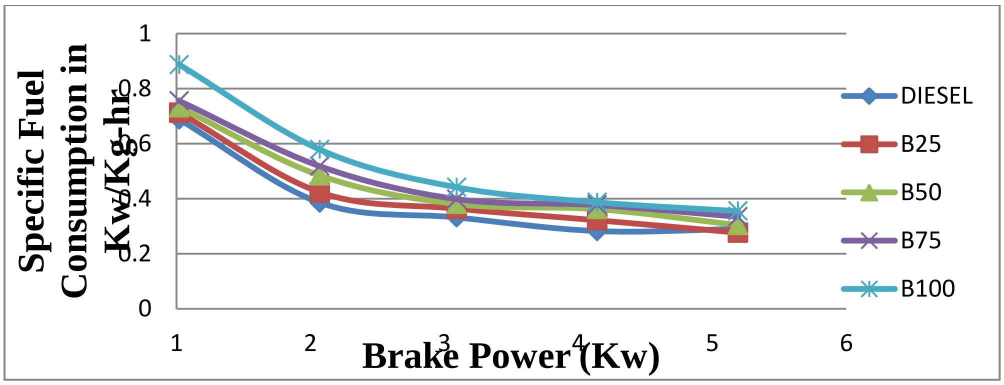

Figure 5.2 Results of Specific Fuel consumption with various Blends

It is noted from the graph of SFC values increases only for the higher brake power. It is due to heating value, density and viscosity of the fuels which is shown in Figure 5.2.

5.3 Brake Thermal Efficiency

The result of Brake Thermal Efficiency (%) of various brake powers with different blends are shown in Table 5.3.

Table 5.3 Results of Brake Thermal Efficiency with various Blends

BRAKE POWER (KW)	DIESEL (ηB.TH) %	B25 (ηB.TH) %	B50 (ηB.TH) %	B75 (ηB.TH) %	B100 (ηB.TH) %
1.0216	12.39	11.70	9.53	8.87	10.75
2.0733	23.24	23.10	17.42	16.35	17.33
3.0950	26.40	24.85	24.32	20.18	43.46
4.1465	29.28	26.16	25.37	25.20	23.59
5.1985	30.43	31.30	25.77	24.57	24.30

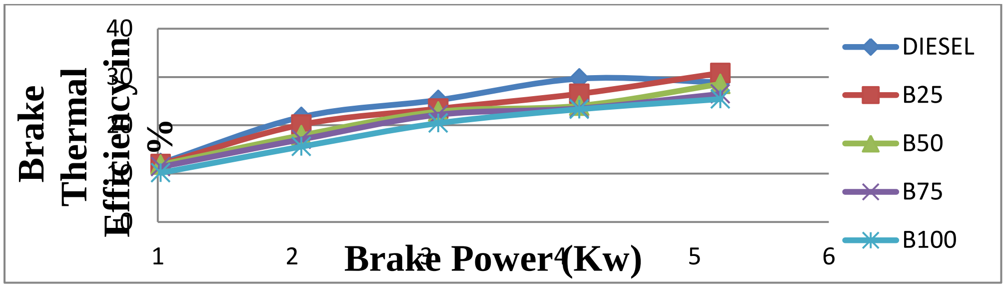

Figure 5.3 Results of Brake Thermal Efficiency with various Blends

It has been observed that when the applied load increases, the Brake thermal efficiency of the fuel also increases. The maximum brake thermal efficiency at full load is 31.30 for B25. By comparing the standard values, it is higher than 1.5% of B25 which is shown in Figure 6.3.

5.4 Exhaust Gas Temperature

The results of exhaust gas temperature of various brake power with different blends are shown in Table 5.4.

Table 5.4 Results of Exhaust Gas Temperature with various Blends

BRAKE POWER (KW)	DIESEL (EGT ˚C)	B25 (EGT ˚C)	B50 (EGT ˚C)	B75 (EGT ˚C)	B100 (EGT ˚C)
1.0216	180	185	190	195	185
2.0733	224	225	250	236	226
3.0950	257	257	263	271	261
4.1465	310	311	301	296	299
5.1985	350	324	326	316	310

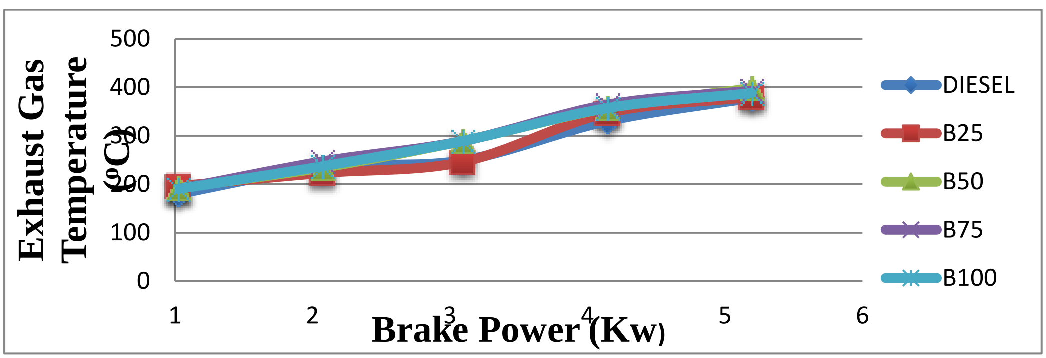

Figure 5.4 Results of Exhaust Gas Temperature with various Blends

It is observed that exhaust gas temperature increases for the biodiesel and diesel blends due to its high compression ratio. Diesel, B25, B50, and B100 have similar exhaust gas temperature and Diesel is higher which is shown in Figure 5.4.

5.5 Nitrogen Oxide

The results of the Nitrogen Oxide of various brake power with different blendsare shown in Table 5.5.

Table 5.5 Results of Nitrogen Oxide with various Blends

BRAKE POWER (KW)	DIESEL NOx(ppm)	B25 NOx(ppm)	B50 NOx(ppm)	B75 NOx(ppm)	B100 NOx(ppm)
1.0216	427	320	286	231	271
2.0733	547	540	510	476	390
3.0950	740	721	684	641	621
4.1465	947	911	864	816	724
5.1985	1210	1124	984	918	763

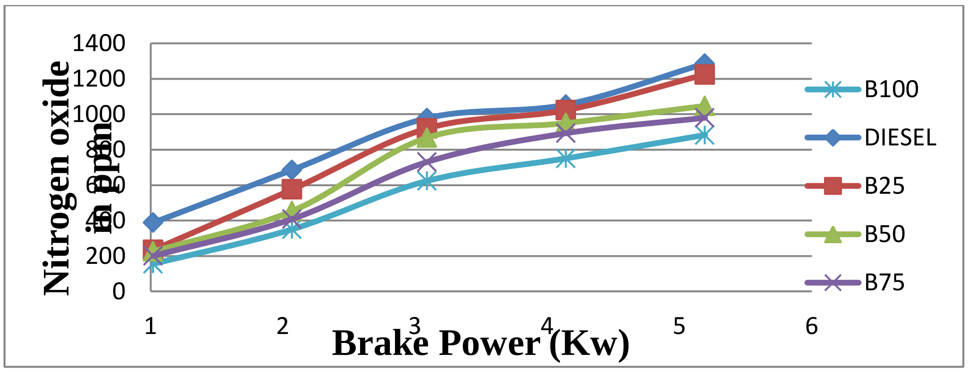

Figure 6.5 Results of Nitrogen Oxide with various Blends

From the graph it is concluded that for higher brake power condition the nitrogen oxide emission from the B100 is lower than that of standard diesel which is shown in Figure 5.5.

5.6 Hydrocarbon

The results of Hydrocarbon of various brake power with different blends are shown in Table 5.6.

Table 5.6 Results of Hydrocarbon with various Blends

BRAKE POWER KW	DIESEL HC (ppm)	B25 HC (ppm)	B50 HC (ppm)	B75 HC (ppm)	B100 HC (ppm)
1.0216	17	12	18	21	20
2.0733	35	26	24	36	29
3.0950	47	38	53	57	36
4.1465	65	49	67	61	41
5.1985	67	57	76	74	55

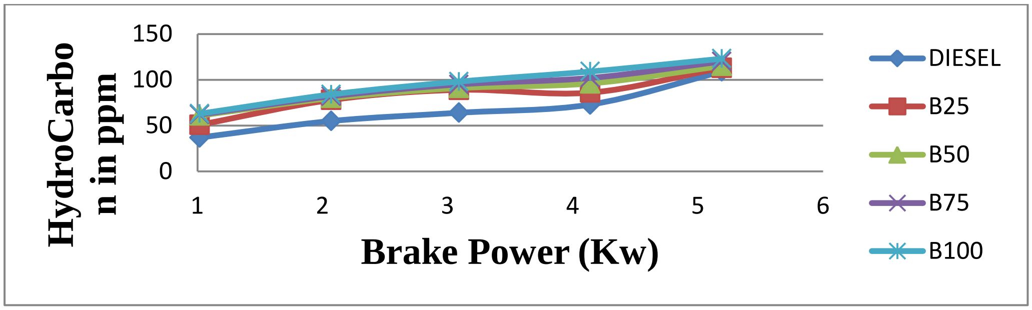

Figure 5.6 Results of Hydrocarbon with various Blends

From the graph it is concluded that for maximum brake power condition the hydrocarbon emission is similar and lower for diesel, B25, B50 and maximum for B50 and B75 which is shown in Figure 5.6.

5.7 Smoke Density

The results of various brake power with different blends are shown in Table 5.7.

Table 5.7 Results of Smoke Density with various Blends

BRAKE POWER (KW)	DIESEL (HSU)	B25 (HSU)	B50 (HSU)	B75 (HSU)	B100 (HSU)
1.0216	20.3	26.8	36	43.7	52.3
2.0733	37.6	48.1	58.3	68	68.1
3.0950	52	59.6	69.8	79.3	89
4.1465	60.1	67	76.3	82.3	90.4
5.1985	65.8	78.3	83.1	85.7	91.5

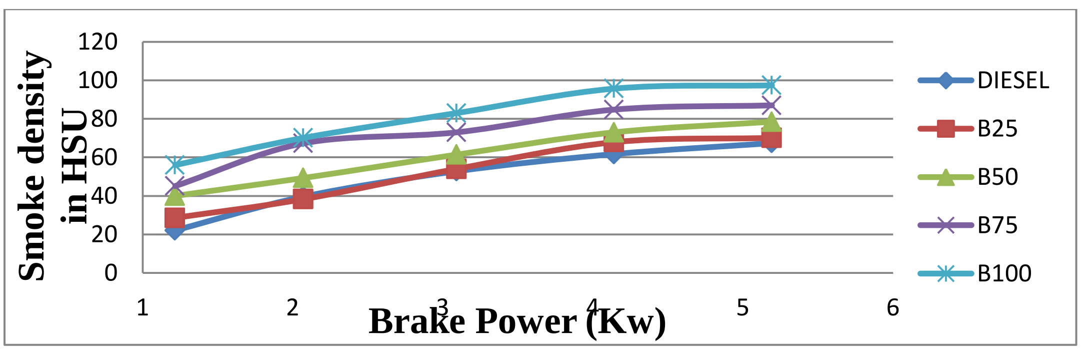

Figure 5.7 Results of Smoke Density with various Blends

It is observed that the smoke density of the exhaust gas increases with increase in brake power for all the blends. At higher brake power condition B100 produces higher amount of smoke density compared to other blends which is shown in Figure 5.7.

5.8 Carbon Monoxide

The results of carbon monoxide of various brake power with different blends are shown in Table 5.8.

Table 5.8 Results of Carbon monoxide with various Blends

BRAKE POWER KW	DIESEL (CO %)	B25 (CO %)	B50 (CO %)	B75 (CO %)	B100 (CO %)
1.0216	0.05	0.05	0.09	0.09	0.09
2.073	0.07	0.06	0.08	0.09	0.09
3.0950	0.07	0.09	0.08	0.08	0.10
4.1465	0.09	0.09	0.09	0.08	0.16
5.1985	0.24	0.24	0.24	0.31	0.17

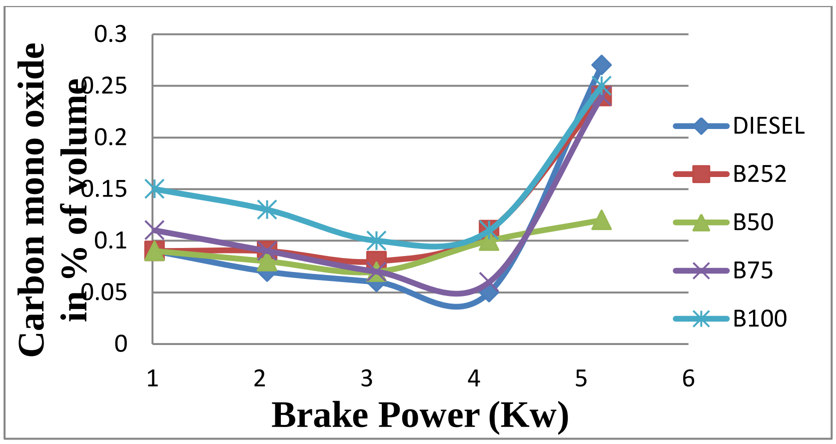

Figure 5.8 Results of Carbon monoxide with various Blends

The carbon monoxide emission of the Diesel is found to be higher for maximum load. Due to rising temperature of the combustion chamber, air fuel ratio, lack of oxygen at high speed, physical and chemical properties of fuel and smaller of time available for complete combustion, the proportion of carbon monoxide emission increase which is shown in Figure 5.8.

6. RESULT & DISCUSSION

- On using the B25, the total fuel consumption is medium, but when compare to diesel it is high.
- On using B25, the specific fuel consumption is medium, but when compare to diesel it is high.
- On using B25, the brake thermal efficiency is high when compare to diesel.
- On using B25, EGT is low,but high when compare to diesel.
- NOx is low in exhaust gas on using B100, but maximum in B25.
- HC is low in exhaust gas on using B25, but maximum in B100.
- Smoke density is low on B25, but maximum in B100.
- Carbon monoxide is low in exhaust gas on using B25, but maximum in pure diesel.
- Then same time nitrogen oxide low in exhaust gas on B50 and B75.
- The highest reduction was for NOx and HC emissions.
- The smoke opacity for biodiesel blends are lower than that of the diesel fuel.
- Biodiesel has higher cetane rating than petrodiesel, which can improve performance and clean up emissions compared to crude petrodiesel.
- Pure biodiesel can be used in any petroleum diesel engine, though it is more commonly used in lower concentrations.

7. CONCLUSIONS

The following conclusions were drawn from through the project,

- From performance analysis it is observed that the performances of diesel blends are similar to diesel.
- The emission nitrogen oxide and smoke were higher than standard diesel for all blends due to their higher viscosity and density.
- As the load increases it gradually increases the exhaust gas temperature. But the mechanical efficiency increases with increase in load.
- Due to ignition delay the cylinder pressure increases for diesel starting at starting and for blend B25. The heat release in low at starting and gradually increases.
- The combustion analysis shows that the cylinder pressure for blends are lower than diesel, emission analysis shows that smoke and nitrogen oxide increase but HC, CO decrease due to less calorific value.
- This process deals with the manufacture of biodiesel an alternative to diesel fuel from vegetable oils.
- This reduction in engine emissions has a penalty and it was reduction of biodiesel performance parameter of the engine in higher percentages of blends.
- The lower biodiesels blends did not have any considerable negative effect on the engine performance.

REFERENCES

[1] Bharath kumar.B, S SKacggwaha, S. Maji and M K G Bahu,"Performance and Emission Analysis of flex seed oil blended with diesel using methyl esters as additive on VCR engine" International journal of modern engineering research ,Vol 69, May 2016.

[2] Ibrahim.M.A, T. Senthilkumar "Performance characteristics of CI engine using biodiesel and preheated Jatropha oil" ARPN Journal of Engineering and Applied Sciences, Vol. 6, No. 2 , 240 – 250, (2015)

[3] Jinlin Xue, M.A. Kalam, H.H. Masjuki, M.H. Jayed "Performance characteristics of CI engine using biodiesel and preheated KARANJI oil", 2nd International Conference on Environmental Science and Technology, Vol.6, 2013.

[4] Kumar Ved, V. K. Gorana1, N. L. Panwar "Biodiesel can be the fuel of the future as it provides an option of economical, eco-friendly, alternative renewable energy source", Journal of Environmental Protection, Vol 2, 454, 2013

[5] Liaquat.A.M, S. Naga Sarada, E.L. Nagesh "Engine performance and emissions analysis using "envo diesel" and coconut biodiesel blended fuel as alternative fuels", International Journal of Automotive and Mechanical Engineering (IJAME), Vol 4, 414 July-December 2011.

[6] Naik.P.L, Puli Ravi kumar ,S. SrinivasaRao "Performance Analysis of CI Engine using Pongamia Pinnata (Karanja) Biodiesel as an alternative Fuel",International Journal of Applied Research in Mechanical Engineering (IJARME), Vol 2, Issue 2, 2012.

[7] Saipad b.b.p.j sahu, Dr. Om prakash "performance and emission characteristics of a diesel engine fuelled with vegetable oil methyl ester blends and diesel blends",International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 5, May 2013.

[8] Sulakshana s. Deshpande, and RavikumarParamasivam"diesel engine performance and emission using ethanol blend fuel" T-ARPN Journal of Engineering and Applied Sciences, ISSN 1819-6608, Vol., Vol 17, No 1, 179 193, 2013.

[9] R.sunilkumar, T. K. Bhattacharya and H. I. Mohammed "investigated the performance and emission characteristics of various dual biodiesel blends" Journal of Environmental Protection. Vol 12, No 1, 179 193, 2014.