Performance and Emission Evaluation of a DI Diesel Engine Using Nerium Oil as Alternative Fuel

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Abstract

Increase in energy demand, stringent emission norms and depletion of oil resources led to find alternative fuels for internal combustion engines. Many alternative fuels like alcohols, biodiesels, liquid petroleum gas (LPG), compressed natural gas (CNG) etc. have been already commercialized in the transport sector. In this context Nerium oil renewed interest. Nerium oil is blended with diesel and used as alternative fuels for CI engine. In the present work the performance characteristics and emissions are evaluated on single cylinder four stroke diesel engine, water cooled which is capable of developing a power output of 7.5kW at 1500rpm, fueling with NO 20%, 30% and 40% of Nerium oil blended with diesel. The performance parameters such as brake power, specific fuel consumption, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency and volumetric efficiency are calculated based on experimental analysis of engine. Emissions such as carbon monoxide (CO), carbon dioxide (CO_2) and unburned hydrocarbons (HC) are measured.

Keywords: *Emissions, Internal combustion engine, Nerium oil and Efficiency.*

1. Introduction

Compression ignition engines are employed particularly in the field of heavy transportation and agriculture on account of their higher thermal efficiency and durability. However, diesel engines are the major contributors of oxides of nitrogen and particulate emissions. Hence more stringent norms are imposed on exhaust emissions. Following the global energy crisis in the 1970s and the increasingly stringent emission norms, the search for alternative renewable fuels has intensified.

Probably in this century, it is believed that crude oil and petroleum products will become very scarce and costly to find and produce. Although fuel economy of engines is greatly improved from the past and will probably continue to be improved, increases in number of automobiles alone dictate that there will be a great demand for fuel in the near future.

2. Literature Survey

The rapid depletion of world petroleum reserves, increases in prices of petroleum based fuels and environmental pollution due to exhaust emissions have encouraged studies to search for alternative fuels. In view of these, vegetable oil has been considered as alternative fuels for compression ignition engines. Vegetable oils are renewable, nontoxic, biodegradable, and have low emission profiles [1–5]. However, there are some drawbacks related to the use of straight vegetable oils in diesel engines primarily due to their high viscosity, lower volatility and lower heat content [6–8].

The high viscosity causes some problems in atomization of injector systems and combustion in cylinders of diesel engines. Also, in long term operations, high viscosity of vegetable oils may lead to ring sticking, formation of injector deposits, development of gumming, as well as incompatibility with lubricating oils [1, 9]. Different techniques have been developed to solve their high viscosity and low volatility problems of vegetable oils, such as preheating oils, blending or dilution with other fuels, transesterification and thermal cracking / pyrolysis [1, 2, 10–12]. Transesterification appears to be the most promising technique which is a chemical process of converting vegetable oil into biodiesel fuel [5, 11, 13 and 14]. Biodiesel can be used as a blend in diesel engines without modification. Detailed reviews about transesterification process are available in the literature [2, 12].

The important compositional difference between biodiesel and the diesel fuel is concerned with oxygen content. Biodiesel contains 10–12% oxygen in weight basis and this lowers the energy content. The lower energy content causes reductions in engine torque and power [7, 15–17]. Biodiesel containing oxygen reduces exhaust emissions such as HC, smoke and CO mainly due to the effect of complete combustion [4, 5, 18–23]. Since biodiesel contains little sulphur compared to the diesel fuel, a significant reduction in SO_2 emission was obtained [24].There is four possible reasons for reduction in particulate emissions. First is the presence of oxygen in fuel rich regions of the combustion fuel spray Second is the modification of radical pool, which inhibits key soot formation reactions and provides OH radicals for oxidation of soot precursors. Third is the removing carbon from soot formation process via C–O bonding within molecule due to oxygen, thereby sequestering carbon from the soot formation process. Fourth is the low level of sulphur content of biodiesel [5]. NOx emissions mainly depend on the engine fuelling system, engine type and engine loading. Two different observations can be seen in the literature. First , higher NOx emissions may be due to higher temperatures of combustion chamber using biodiesel [18].This is also evident from higher exhaust gas temperatures from biodiesel fuelled engines [11].However, some studies showed lower NOx emissions [4,5,24]. This is because higher cetane numbers of biodiesel shortens the ignition delay. The amount of premixed fuel and peak burning temperature are reduced, leading to the reduction in NOx emissions [5].

The price of edible vegetable oils is higher than that of the diesel fuel. Therefore, instead of using such oils, use of waste vegetable oils [18 and non-edible crude vegetable oils [11] have been considered as potential alternative fuels.

A single cylinder stationary kirloskar engine is used to compare the Performance, Emission and Combustion characteristics between pure diesel and Nerium blends [24]. The Nerium oil blends are in percentage of 20%, 40%, 60%, 80%, and 100% of Nerium oil to 80%, 60%, 40%, 20% and 0% of diesel. Results show that methyl esters of Nerium oil (MEON) produced slightly higher efficiency than ethyl esters of Nerium oil (EEON). Exhaust emissions and Combustion characteristics of methyl esters of Nerium oil (MEON) were also higher than ethyl esters of Nerium oil (EEON). Hence methyl and ethyl esters of Nerium blend can be used in existing diesel engines without compromising the engine performance.

In the present investigation, Nerium oil, that is non-edible oil, was considered as a potential alternative fuel for compression ignition engines. Specifications of the Nerium oil investigated and compared these specifications with other vegetable oils and this was the basic motivation behind the research in this paper. The engine tests were carried out on a direct injection diesel engine fuelled with diesel fuel and 20%, 30% and 40% Nerium oil-diesel blends by volume. The results were summarized.

3. Materials and Methods

Rapid depletion of conventional energy sources, along with increasing demand for energy is a matter of serious concern. To solve both the energy concern and environmental concern, the renewable energies with lower environmental pollution impact should be necessary. Biodiesel is renewable and environmental friendly alternative diesel fuel for diesel engine. It can be produced by trans-esterification process. Trans-esterification is a chemical reaction in which vegetable oils and animal fats are reacted with alcohol in the presence of a catalyst. The products of reaction are fatty acid alkyl ester and glycerin, and were the fatty acid alkyl esters known as biodiesel.

3.1. Transesterification of Nerium Oil

To reduce the viscosity of the Nerium oil, trans-esterification method is adopted for the preparation of biodiesel.

3.2. Methyester of Nerium Oil

The procedure involved in this method is as follows: 1000 ml of Nerium oil is taken in a three way flask. 12 grams of sodium hydroxide (NaOH) and 200 ml of methanol (CH_3OH) are taken in a beaker. The sodium hydroxide (NaOH) and the alcohol are thoroughly mixed until it is properly dissolved. The solution obtained is mixed with Nerium oil in three way flask and it is stirred properly.

The methoxide solution with Nerium oil is heated to 60 ^{0}C and it is continuously stirred at constant rate for 1 hour by stirrer. The solution is poured down to the separating beaker and is allowed to settle for 4 hours. The glycerin settles at the bottom and the methyl ester floats at the top (coarse biodiesel). Methyl ester is separated from the glycerin. This coarse biodiesel is heated above 100°C and maintained for 10-15 minutes to remove the untreated methanol. Certain impurities like sodium hydroxide (NaOH) etc are still dissolved in the obtained coarse biodiesel. These impurities are cleaned up by washing with 350 ml of water for 1000 ml of coarse biodiesel. This cleaned biodiesel is the methyl ester of Nerium oil.

3.3. Ethyl Ester of Nerium Oil

The procedure involved in this method is as follows: 1000 ml of Nerium oil is taken in a three way flask. 12 grams of sodium hydroxide (NaOH) and 200 ml of Ethanol (C_2H_5OH) are taken in a beaker. The sodium hydroxide (NaOH) and the alcohol are thoroughly mixed until it is properly dissolved. The solution obtained is mixed with Nerium oil in three way flask and it is stirred properly. The ethoxide solution with Nerium oil is heated to 60°C and it is continuously stirred at constant rate for 1 hour by stirrer. The solution is poured down to the separating beaker and is allowed to settle for 4 hours. The glycerin settles at the bottom and the ethyl ester floats at the top (coarse biodiesel). Ethyl ester is separated from the glycerin. This coarse biodiesel is heated above 100°C and maintained for 10-15 minutes to remove the untreated ethanol. Certain impurities like sodium hydroxide (NaOH) etc are still dissolved in the obtained coarse biodiesel. These impurities are cleaned up by washing with 350 ml of water for 1000 ml of coarse biodiesel. This cleaned biodiesel is the Ethylester of Nerium oil. This bio-diesel of methyl ester of Nerium oil and ethyl ester of Nerium oil was then blended with mineral diesel in various concentrations for preparing biodiesel blends to be used in CI engine for conducting various engine tests.

Table No. 1. Properties of Nerium Oil

Properties	Diesel	Nerium oil
Kinematic viscosity at 40 ^{0}C (cSt)	3.52	4.88
Density at 15 ^{0}C (kg/m^3)	830	910
Flash point (^{0}C)	49	148
Calorific value (kJ/kg)	42000	36570
Sp.gravity	0.83	0.91

4. Specification of the Problem

In the present work the performance characteristics and emissions are evaluated on single cylinder four stroke diesel engine, water cooled which is capable of developing a power output of 7.5kW at 1500rpm, fueling with TPO 20%, 30% and 40% of Nerium oil blended with diesel. The performance parameters such as brake power, specific fuel consumption, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency and volumetric efficiency are calculated based on experimental analysis of engine. Emissions such as carbon monoxide (CO), carbon dioxide (CO_2) and unburned hydrocarbons (HC) are measured.

5. Experimental Setup

The experimental setup is fabricated to fulfill the objective of the present work. The various components of the experimental set up including modification are shown in fig no.1.
Various Parts of Experimental Setup

1. Alamgair Engine
2 Alternator
3. Diesel Tank
4. Air Filter
5. Three Way Valve
6. Exhaust Pipe
7. Probe
8. Exhaust Gas Analyser
9. Alternative Fuel Tank
10. Burette
11. Three Way Valve
12. Control Panel

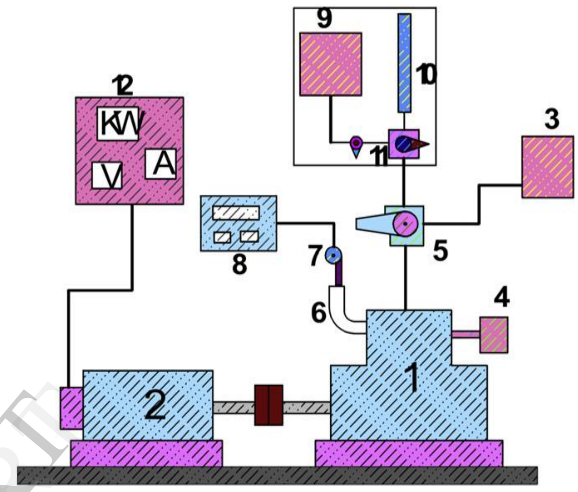

Figure No.1. Experimental Setup

5.1 Experimental Procedure

Before starting the engine, the lubricating oil level in the engine is checked and it is also ensured that all moving and rotating parts are lubricated.
The various steps involved in the setting of the experiments are

1. The Experiments were carried out after installation of the engine
2. The injection pressure is set at 200 bar for the entire test.
3. Precautions were taken, before starting the experiment.
4. Always the engine was started with no load condition
5. The engine was started at no load condition and allowed to work for at least 10 minutes to stabilize.
6. The readings such as fuel consumption, spring balance reading, cooling water flow rate, manometer reading etc., were taken as per the observation table.
7. The load on the engine was increased by 20% of FULL Load using the engine controls and the readings were taken as shown in the tables.
8. Step 3 was repeated for different loads from no load to full load.

6. Results and Discussions

Experiments were conducted when the engine was fuelled with Nerium oil and their blends with diesel in proportions of 20:80, 30:70 and 40:60 (by volume) which are generally called as NO-20, NO-30 and NO-40 respectively. The experiment covered a range of loads. The performance of the engine was evaluated in terms of brake specific fuel consumption, brake thermal efficiency and volumetric efficiency shown in corresponding graphs and figures.

The emission characteristics of the engine were studied in terms exhaust gas temperature, concentration of HC, CO and CO_2. The results obtained for Nerium oil and their blends with diesel were compared with the results of diesel.

Table No. 2. Performance and Emission Test Results at Pure Diesel

S.N0	Load	Speed	Time	B.P	TFC	I.P	F.P	Heat Input	BSFC	η_{bth}	η_{ith}	η_{mech}	η_{vol}	BMEP	IMEP	CO	HC	CO_2
	W	Rpm	Sec	kW	kg/s $*10^{-4}$	kW	kW	kW	Kg/ kW h	%	%	%	%	kN/m^2	kN/m^2	%vol	ppm	%vol
1	0	1500	80.21	0	2.119	2.312	1.5	8.9	0	0	25.98	0	66.01	0	170.76	0.02	10	1.1
2	1000	1500	55.68	1.469	2.736	3.019	1.5	11.491	0.67	12.76	26.27	48.67	66.83	124	232.93	0.02	18	1.3
3	2000	1500	47.9	2.401	3.586	3.951	1.5	15.062	0.537	17.46	26.23	60.77	67.51	202.69	325.29	0.02	26	1.4
4	3000	1500	39.67	3.118	4.285	4.668	1.5	17.999	0.494	19.12	25.93	66.78	68.46	263.26	394.1	0.02	30	1.5
5	4000	1500	30.21	3.765	5.627	5.351	1.5	23.634	0.537	18.06	22.47	70.84	68.93	317.87	451.75	0.015	35	1.5
6	5000	1500	22.63	4.068	7.511	5.618	1.5	31.547	0.664	16.45	17.8	72.44	68.73	343.9	462.67	0.01	41	1.6

Table No. 3 . Performance and Emission Test Results at NO 20

S.No	Load	Speed	Time	B.P	TFC	I.P	F.P	Heat Input	BSFC	η_{bth}	η_{ith}	η_{mech}	η_{vol}	BMEP	IMEP	CO	HC	CO_2
	W	rpm	Sec	kW	kg/s $*10^{-4}$	kW	kW	kW	Kg/ kW h	%	%	%	%	kN/m^2	kN/m^2	%vol	ppm	%vol
1	0	1500	83.5	0	2.04	1.5	1.5	8.568	0	0	25	0	44.02	0	181.6	0.02	15	1
2	1000	1500	63.07	1.377	2.72	2.87	1.5	11.424	0.627	12.60	25.12	47.9	48.17	116.32	243.32	0.03	21	1
3	2000	1500	52.85	2.505	3.37	4.005	1.5	14.154	0.506	17.69	23.34	62.54	51.36	211.68	337.28	0.04	23	1.4
4	3000	1500	44.01	3.40	4.08	4.901	1.5	17.136	0.453	19.8	23.23	69.39	54.62	288.77	413.37	0.06	24	1.3
5	4000	1500	36.9	3.86	4.98	5.36	1.5	20.91	0.486	18.45	25.16	72.0	55.44	325.54	452.14	0.15	24	1.5
6	5000	1500	28.12	4.2	6.20	5.7	1.5	26.04	0.531	16.12	21.83	73.68	58.70	354.70	481.30	0.36	32	1.6

Table No. 4. Performance and emission test Results at NO 30

S.N0	Load	Speed	Time	B.P	TFC	I.P	F.P	Heat Input	BSFC	η_{bth}	η_{ith}	η_{mech}	η_{vol}	BMEP	IMEP	CO	HC	CO_2
	W	rpm	Sec	kW	kg/s $*10^{-4}$	kW	kW	kW	Kg/ kW h	%	%	%	%	kN/m^2	kN/m^2	%vol	ppm	%vol
1	0	1500	94.25	0	1.846	2.193	1.7	7.845	0	0	27.9	0	36.69	0	185.06	0.01	7	0.4
2	1000	1500	68.4	1.530	2.54	2.93	1.7	10.795	0.597	14.17	27.14	52.2	39.95	129.16	247.25	0.02	9	0.6
3	2000	1500	54	2.409	3.22	3.801	1.7	13.685	0.478	17.60	27.7	63.19	44.02	203.30	320.75	0.02	9	0.7
4	3000	1500	45.01	3.47	3.86	4.872	1.7	16.405	0.396	21.16	29.60	71.2	47.28	292.9	411.19	0.04	12	0.8
5	4000	1500	36.08	4.26	4.82	5.66	1.7	20.485	0.406	20.81	27.62	75.31	50.55	359.49	477.63	0.11	1	1
6	5000	1500	28.70	4.387	6.06	5.78	1.7	25.75	0.497	17.3	22.44	75.89	55.49	370.21	487.76	0.25	8	1.1

Table No. 5 Performance and emission test Results at NO 40

S.N0	Load	Speed	Time	B.P	TFC	I.P	F.P	Heat Input	BSFC	η_{bth}	η_{ith}	η_{mech}	η_{vol}	BMEP	IMEP	CO	HC	CO_2
	W	rpm	Sec	kW	kg/s $*10^{-4}$	kW	kW	kW	Kg/ kW h	%	%	%	%	kN/m^2	kN/m^2	%vol	ppm	%vol
1	0	1500	88.15	0	2.04	1.993	2	8.69	0	0	22.9	0	35.05	0	168.18	0.03	10	0.8
2	1000	1500	67.01	1.530	2.68	2.73	2	11.41	0.63	13.41	23.9	56	38.32	129.16	230	0.03	18	0.7
3	2000	1500	54.52	2.409	3.28	3.609	2	13.59	0.496	17.19	25.76	66.7	42.39	203.3	304.58	0.03	12	0.8
4	3000	1500	45.18	3.33	3.98	4.53	2	16.40	0.43	20.35	27.6	73.50	45.65	281.01	382.2	0.04	14	0.7
5	4000	1500	37.13	4.172	4.82	5.3	2	20.53	0.414	20.31	25.81	78.81	51.36	352.6	447	.014	12	1
6	5000	1500	29.94	4.40	6.15	5.6	2	26.19	0.5	16.8	21.3	78.5	52.18	371	472.52	0.22	12	1.2

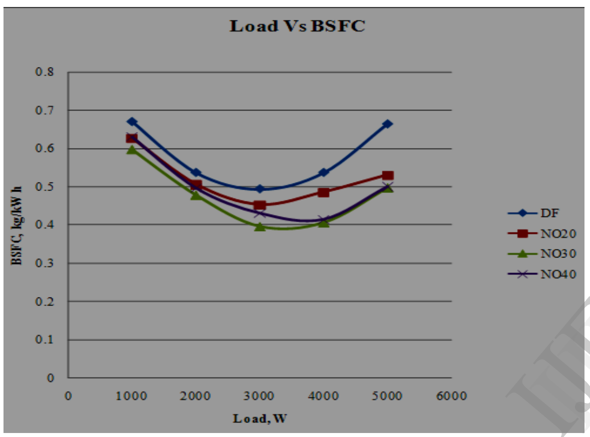

Figure No.2. Load Vs B.S.F.C

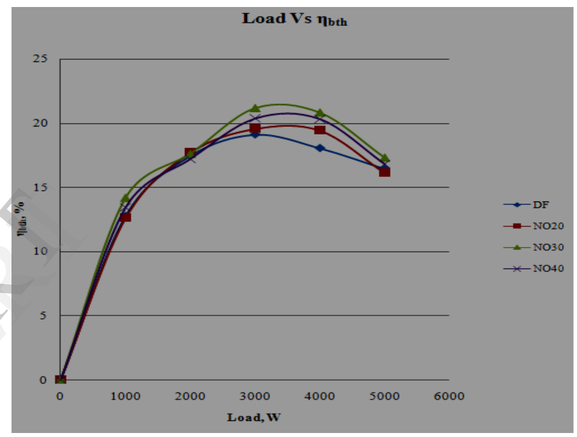

Figure No.4 Load Vs Brake Thermal Efficiency

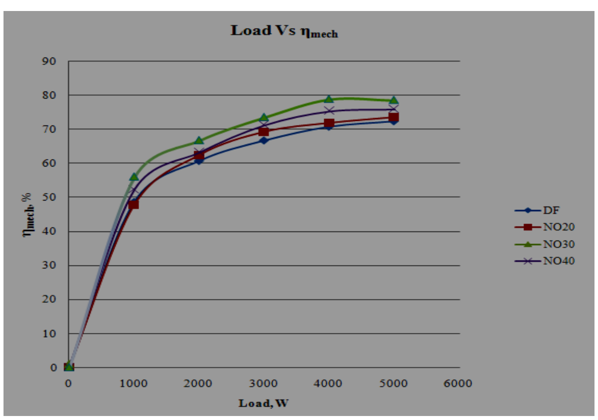

Figure No.3 Load Vs Mechanical efficiency

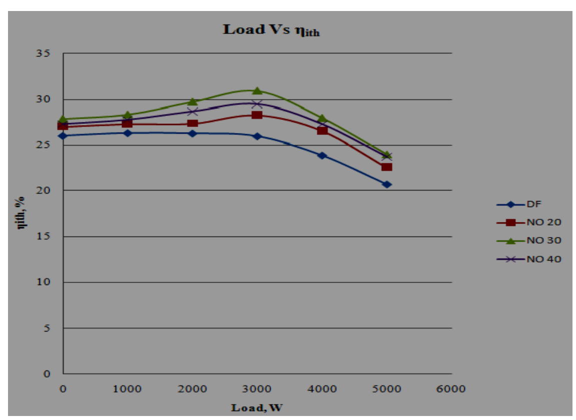

Figure No.5 Load Vs Indicated Thermal Efficiency

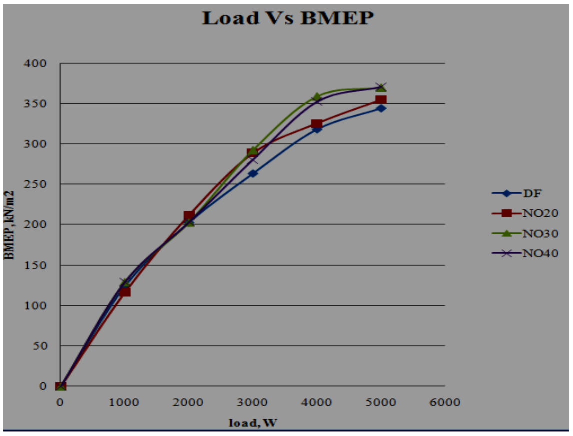

Figure No.6 Load Vs Brake Mean Effective Pressure

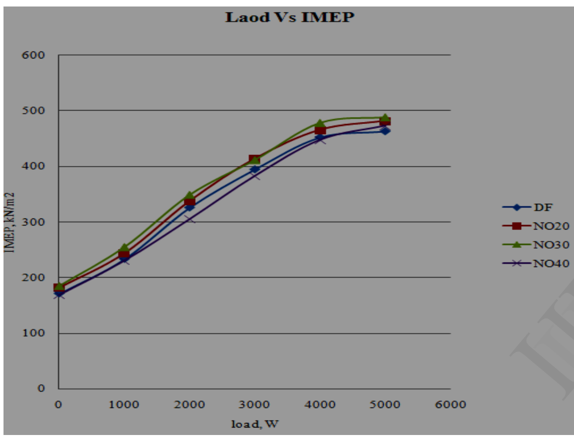

Figure No.7 Load Vs Indicated Mean Effective Pressure

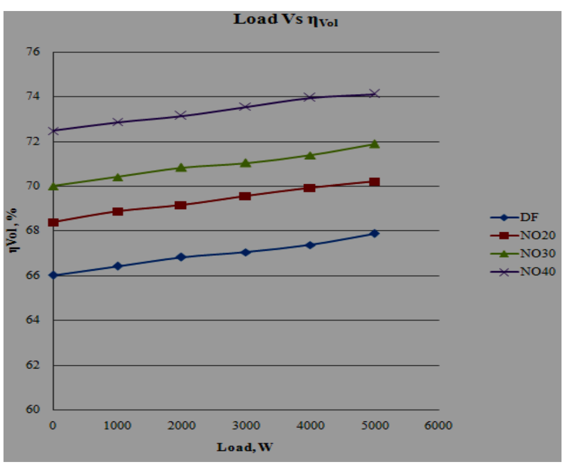

Figure No.8 Load Vs Volumetric Efficiency

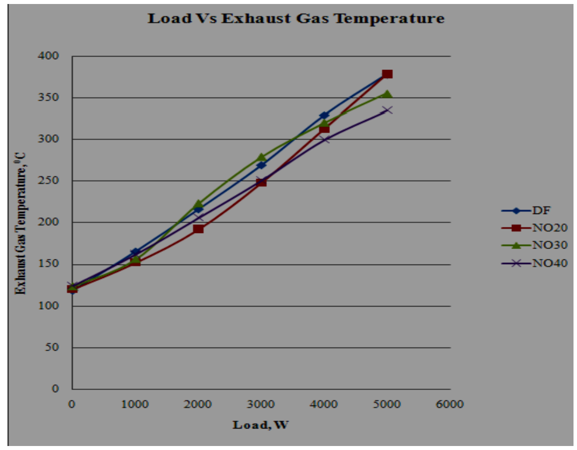

Figure No.9 Load Vs Exhaust Gas Temperature

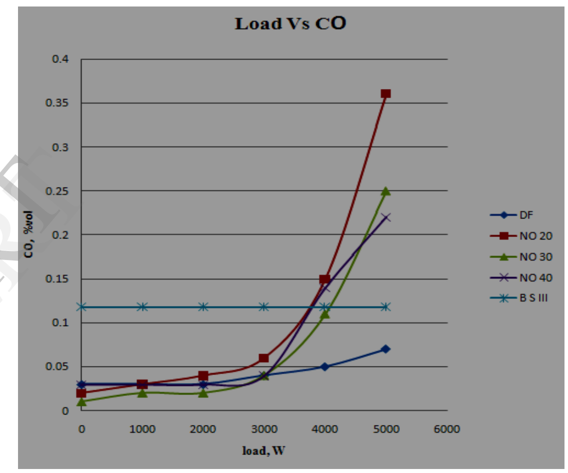

Figure No.10 Load Vs Carbon monoxide

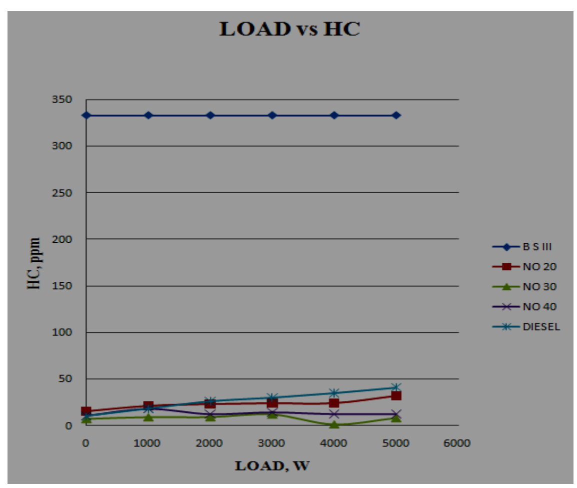

Figure No.11 Load Vs Hydrocarbons

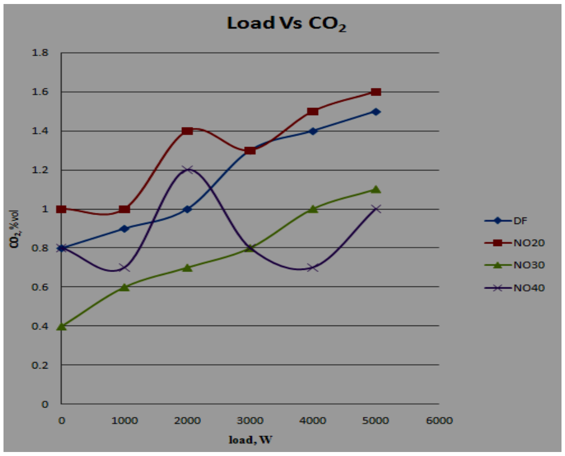

Figure No.12. Load Vs Carbon dioxide

7. Conclusion

Following are the conclusions based on the experimental results obtained while operating single cylinder air cooled diesel engine fuelled with Nerium Oil and its diesel blends.

- The blends of Nerium oil show lowest specific fuel consumption than the diesel at part loads. B.S.F.C is decreased the blend NO.
- Brake Thermal efficiency of the tested diesel engine is improved when it is fuelled with Nerium oil-diesel blends.
- Mechanical efficiency for NO 30 is higher compared to Diesel fuel operation is observed.
- Brake mean effective pressure is also increased as the percentage of the Nerium oil increases with the diesel. But this increment in Brake mean effective power is insignificant.
- Actual Breathing capacity of the engine also slightly increased which leads to increase in volumetric efficiency. It is noted that the volumetric efficiency is raised as the blend of the Nerium oil increases in the diesel.
- CO emission decrease with increase in percentage of Nerium oil in the fuel up to 3000W.
- CO_2 emissions of Nerium oil and its diesel blends are slightly lower than that of diesel. HC emissions of Nerium oil and its diesel blends are lower than that of diesel.

From the above analysis the main conclusion is Nerium oil and its diesel blends are suitable substitute for diesel as they produce lesser emissions than diesel upto a load of 3000W and have satisfactory combustion and performance characteristics.

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