IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 2 Ver. V (Mar - Apr. 2015), PP 37-44
www.iosrjournals.org

Effect of Varying Load on Performance and Emission of C.I. Engine Using WPO Diesel Blend

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Abstract : *Diesel engines are widely used in heavy duty applications like transportation, power generation etc. but the quantity of diesel is limited in the world. So the price of diesel increased as the use of diesel increased day by day. With increase in use of these fossil fuels environmental problem is one of the issues which are increased day by day. These environmental concern and limited quantity of fuels have caused interests in the search for alternative fuels for IC engine. This paper represents the effect of varying load on performance and emission of diesel engine using WPO diesel blend in different proportion. Experiment was carried out by taking 0%, 10%, 20% and 30% WPO diesel blend. Experimental results shows that SFC decreases with increase in load but ME and BTE increases in all blend and 30% WPO diesel blend has minimum SFC and higher BTE and ITE compare to other blend proportion. Emission results show that emission of HC, NO_X and CO_2 increases with increase in load. With compare to diesel Emission of CO and CO_2 is lower in 30% blend and NO_X emission is lower at higher load but emission of HC increased. So diesel engine can be run at 30% WPO diesel blend.*
Keywords – *Blended fuel, Diesel fuel, Engine Performance, Engine Emission*

I. Introduction

With time passing by, the fossil fuel reserves are depleting at a faster rate, causing continuous increase in price of petroleum products all over the world. The high price of petroleum products is a big concern for Indian economy. India imports on an average 80% of total demand of crude oil. Therefore an alternative cheaper fuel is required to fulfil the needs of common man.

Alternative source of fuel lies in plastic. In India 56 lakh tones of plastics are generated each year and only 60% of it is recycled. Safe method of disposing the waste plastic has not yet been implemented here, and dumping of waste plastic underground is hazardous to the environment. But we can use it as an alternative source of fuel for diesel. This will save the environment from hazardous effect as well as to boosting the Indian economy. Previously, many researches were done experiment on alternative fuels. All of them showed encouragement results. However, the drive for search of a new source of alternative fuel, we have performed the engine performance test by using Waste Plastic oil + Diesel of various blends viz. B10, B20, B30. We found that the blends of Diesel & Waste Plastic Oil gives better values to Diesel fuel in the Kirloskar Diesel engine, without any further modification in the engine itself. [1]

II. Literature Review

Sachin kumar et al. (2013) have been used blend of diesel and waste plastic oil as a fuel in diesel engine and check performance and analysis of engine. The experimental results show that the SFC increases with increase in WPO blend ratio and decreases with increase in engine load. Mechanical efficiency increases with increasing brake power for all fuel blends. The unburnt hydrocarbon emission decreases with increase in the engine load and increases with increase in percentage of waste plastic oil in blends. The carbon dioxide emission for the blends is lower than diesel for almost all loads and all blends [2].

G. Nagarajan et al. (2010) have been used blend of diesel and waste plastic oil and it is observed that the engine could operate with 100% waste plastic oil and can be used as fuel in diesel engines. NOx was higher by about 25% and carbon monoxide (CO) increased by 5% for waste plastic oil operation compared to diesel fuel (DF) operation. Hydrocarbon was higher by about 15%. Engine fueled with waste plastic oil exhibits higher thermal efficiency up to 80% of the full load compared to DF operation [3].

M. Mani et al. (2009) have been used waste plastic oil as a fuel. In the present work, the influence of injection timing on the performance, emission and combustion characteristics of a single cylinder, four stroke, direct injection diesel engine has been experimentally investigated using waste plastic oil as a fuel. Tests were performed at four injection timings (23, 20, 17 and 14 bTDC). When compared to the standard injection timing of 23 BTDC the retarded injection timing of 14 bTDC resulted in decreased oxides of nitrogen, carbon monoxide and unburned hydrocarbon while the brake thermal efficiency, carbon dioxide and smoke increased under all the test conditions [4].

M. Mani et al. (2009) have been used waste plastic oil as a fuel. Investigation was to study the effect of cooled exhaust gas recirculation (EGR) on four stroke, single cylinder, direct injection (DI) diesel engine using 100% waste plastic oil. An experimental result shows that NOx emissions were reduced when the engine was operated with cooled EGR[5].

III. Waste Plastic Oil

Waste plastic oil or pyrolysis oil is the chemical product from decomposition process of organic substance (waste plastic) by heating. The waste plastic is treated in cylindrical reactor at temperature 400-500 degree Celsius without oxygen. This pyrolysis process can also be used to produce liquid fuel similar to diesel. Presently, pyrolysis oil or oil from waste plastic widely use in dual fuel-generator set for generation electricity, marine diesel engine, and agriculture engine. Oil is the main product of pyrolysis process. Plastic scrap or waste plastic is used as raw material for pyrolysis process. The properties of waste plastic oil and diesel fuel are shown in Table 1. [6]

Table -1: Property of WPO and diesel

Property	Diesel	Waste plastic oil
Cetane number	55	51
Viscosity (cst)	2.0 (at 40 C)	1.69 (at 40 C)
Density(gm/cc)	0.832	0.788
CV(kj/kg)	42000	58341
Flash point	50	22
Sulfur (% by mass)	0.045	0.01

IV. Experimental Setup

To The experiments were conducted on a single-cylinder, 4-Stroke, water-cooled diesel engine of 5 HP rated power. The engine is coupled to a rope brake dynamometer through a load cell. A five exhaust gas analyzer was used for measuring NO_X, CO_2, HC and CO. The exhaust gas analyzer determined the emissions of NO_X, CO2, HC and CO by means of electrochemical sensors. The experimental setup is shown in below Figure 1-

Figure -1: Engine Setup

Table -2: Engine Specifications

Parameter	Details
Engine	Single cylinder diesel engine
Cooling	Water cooled
Bore × Stroke	80 mm × 110 mm
Compression ratio	16 : 1
Maximum Power	5 hp or 3.7 kW
Rated speed	1500 rpm
Capacity	553 CC

V. Methodology

In this experiment, diesel engine connected with the rope brake dynamometer. By using dynamometer, varies the load on the engine and gas analyzer is utilized to quantify the emission from exhaust gas. The readings are taken at varying the load from 1 to 11kg by keeping injection pressure constant at 190psi.

To perform this experiment, the first set of load varying (1 to 11kg) was carried out with a conventional diesel engine using 0% WPO diesel blend. Then after different blend ratio of WPO diesel blend of 10%, 20% and 30% respectively were selected and fuel consumption was recorded at every time to calculate performance of engine at every stage. The data for HC, NOx, CO and CO_2 were recorded by exhaust gas analyze**r.**

VI. Observation Tables And Graph

Observation table and graphs of performance and emission using 0%, 10%, 20% and 30% WPO Diesel blend are shown as below.

Table – 3: Engine Performance using diesel fuel

100% diesel										
Load (kg)	FC (mm)	Torque (Nm)	BP (kw)	FC (kg/h)	SFC (kg/kwh)	FP (kw)	IP (kw)	mech. Eff.(%)	BTE (%)	ITE (%)
1.00	12.50	1.38	0.22	0.31	1.44	1.80	2.02	10.77	5.97	55.42
2.00	13.00	2.77	0.43	0.32	0.75	1.80	2.23	19.44	11.47	59.02
3.00	13.50	4.15	0.65	0.34	0.52	1.80	2.45	26.58	16.57	62.36
4.00	14.50	5.53	0.87	0.36	0.42	1.80	2.67	32.55	20.57	63.20
5.00	15.50	6.92	1.09	0.39	0.36	1.80	2.89	37.63	24.06	63.94
6.00	16.60	8.30	1.30	0.41	0.32	1.80	3.10	41.99	26.96	64.19
7.00	18.00	9.68	1.52	0.45	0.30	1.80	3.32	45.79	29.00	63.34
8.00	19.50	11.07	1.74	0.49	0.28	1.80	3.54	49.11	30.60	62.29
9.00	21.00	12.45	1.95	0.52	0.27	1.80	3.75	52.06	31.96	61.40
10.00	22.00	13.83	2.17	0.55	0.25	1.80	3.97	54.68	33.90	61.99
11.00	23.50	15.22	2.39	0.59	0.25	1.80	4.19	57.03	34.91	61.21

Table – 4: Engine Performance using 10% WPO Diesel blended fuel

10% WPO 90% diesel										
Load (kg)	FC (mm)	Torque (Nm)	BP (kw)	FC (kg/h)	SFC (kg/kwh)	FP (kw)	IP (kw)	mech. Eff.(%)	BTE (%)	ITE (%)
1.00	11.40	1.38	0.22	0.28	1.30	2.09	2.31	9.41	6.58	69.87
2.00	12.50	2.77	0.43	0.31	0.71	2.09	2.52	17.21	12.00	69.72
3.00	13.50	4.15	0.65	0.34	0.51	2.09	2.74	23.76	16.66	70.11
4.00	14.90	5.53	0.87	0.37	0.43	2.09	2.96	29.36	20.13	68.55
5.00	16.50	6.92	1.09	0.41	0.38	2.09	3.18	34.19	22.72	66.45
6.00	18.00	8.30	1.30	0.45	0.34	2.09	3.39	38.40	24.99	65.08
7.00	18.50	9.68	1.52	0.46	0.30	2.09	3.61	42.11	28.37	67.37
8.00	18.70	11.07	1.74	0.46	0.27	2.09	3.83	45.39	32.07	70.66
9.00	20.00	12.45	1.95	0.50	0.25	2.09	4.04	48.32	33.74	69.81
10.00	21.40	13.83	2.17	0.53	0.24	2.09	4.26	50.96	35.03	68.75
11.00	22.60	15.22	2.39	0.56	0.23	2.09	4.48	53.34	36.49	68.42

Table – 5: Engine Performance using 20% WPO Diesel blended fuel

20% WPO 80% diesel										
Load (kg)	FC (mm)	Torque (Nm)	BP (kw)	FC (kg/h)	SFC (kg/kwh)	FP (kw)	IP (kw)	mech. Eff.(%)	BTE (%)	ITE (%)
1.00	10.30	1.38	0.22	0.25	1.17	1.88	2.10	10.36	7.32	70.67
2.00	12.40	2.77	0.43	0.31	0.71	1.88	2.31	18.77	12.16	64.78
3.00	13.50	4.15	0.65	0.33	0.51	1.88	2.53	25.74	16.75	65.08
4.00	14.40	5.53	0.87	0.36	0.41	1.88	2.75	31.60	20.94	66.25
5.00	15.40	6.92	1.09	0.38	0.35	1.88	2.97	36.61	24.47	66.84
6.00	17.20	8.30	1.30	0.42	0.33	1.88	3.18	40.94	26.29	64.23
7.00	17.80	9.68	1.52	0.44	0.29	1.88	3.40	44.71	29.64	66.30
8.00	19.00	11.07	1.74	0.47	0.27	1.88	3.62	48.03	31.74	66.08
9.00	20.40	12.45	1.95	0.50	0.26	1.88	3.83	50.97	33.25	65.24
10.00	20.70	13.83	2.17	0.51	0.24	1.88	4.05	53.60	36.41	67.93
11.00	22.00	15.22	2.39	0.54	0.23	1.88	4.27	55.96	37.69	67.35

Table – 6: Engine Performance using 30% WPO Diesel blended fuel

30% WPO 70% diesel										
Load (kg)	FC (mm)	Torque (Nm)	BP (kw)	FC (kg/h)	SFC (kg/kwh)	FP (kw)	IP (kw)	mech. Eff.(%)	BTE (%)	ITE (%)
1.00	11.60	1.38	0.22	0.28	1.31	2.16	2.38	9.14	6.53	71.51
2.00	12.50	2.77	0.43	0.31	0.71	2.16	2.59	16.74	12.12	72.42
3.00	13.90	4.15	0.65	0.34	0.52	2.16	2.81	23.17	16.35	70.58
4.00	15.00	5.53	0.87	0.37	0.42	2.16	3.03	28.68	20.21	70.46
5.00	16.30	6.92	1.09	0.40	0.37	2.16	3.25	33.45	23.24	69.48
6.00	16.80	8.30	1.30	0.41	0.32	2.16	3.46	37.63	27.06	71.93
7.00	18.00	9.68	1.52	0.44	0.29	2.16	3.68	41.31	29.47	71.34
8.00	19.20	11.07	1.74	0.47	0.27	2.16	3.90	44.58	31.57	70.83
9.00	20.10	12.45	1.95	0.49	0.25	2.16	4.11	47.50	33.93	71.43
10.00	21.00	13.83	2.17	0.52	0.24	2.16	4.33	50.13	36.08	71.98
11.00	22.70	15.22	2.39	0.56	0.23	2.16	4.55	52.51	36.72	69.92

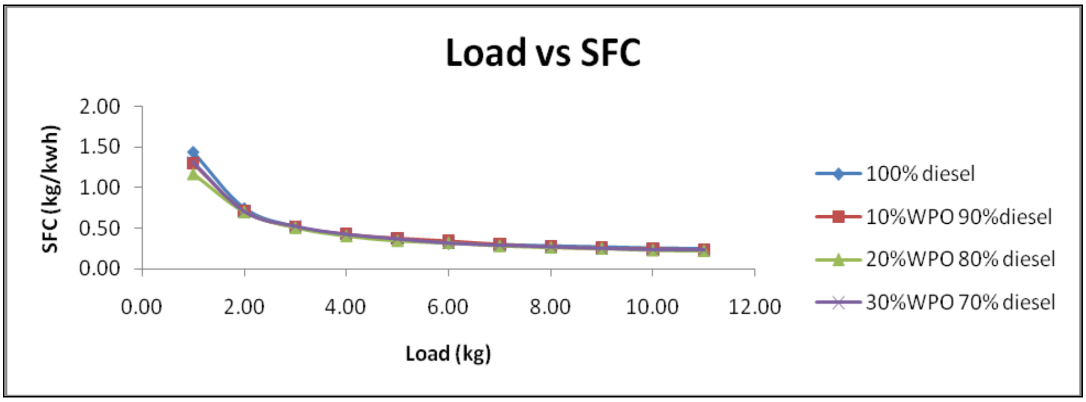

Figure – 2: Load vs SFC graph in all blend

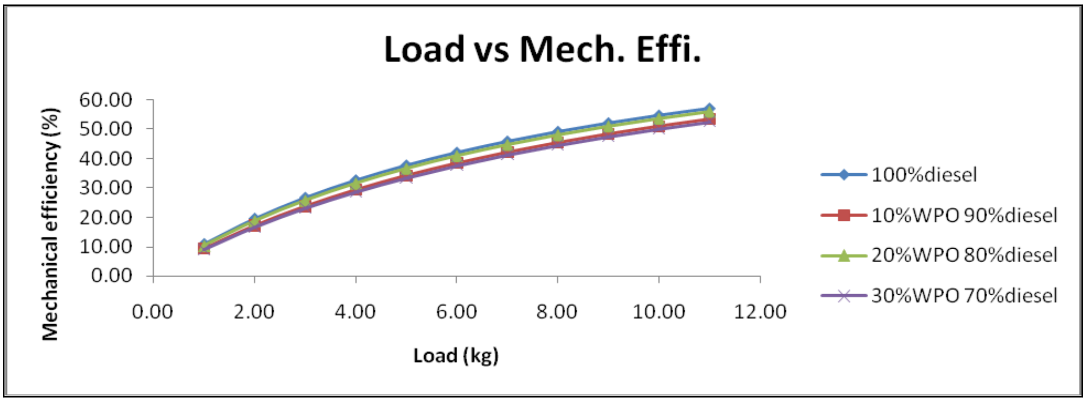

Figure – 3: Load vs Mech. Effi. graph in all blend

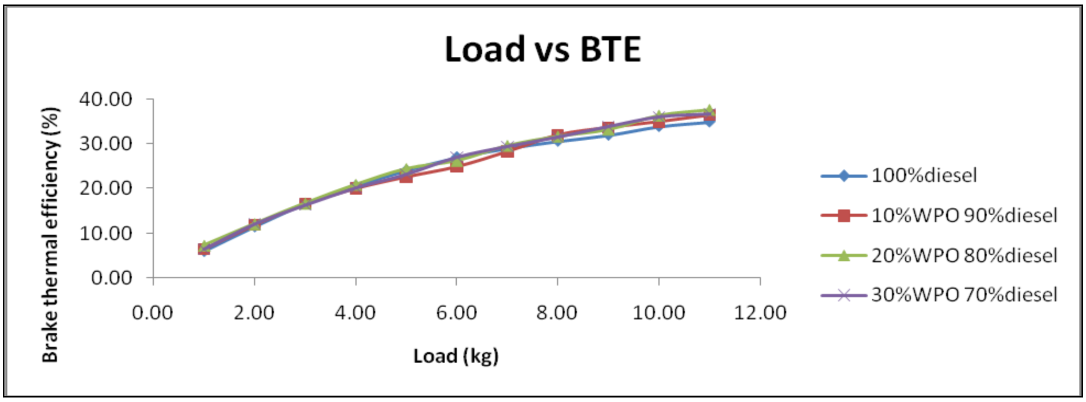

Figure – 4: Load vs BTE graph in all blend

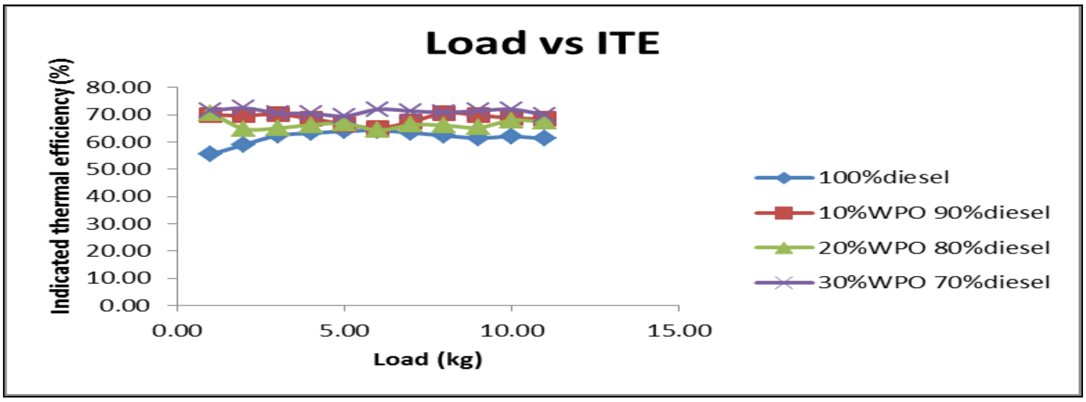

Figure – 5: Load vs ITE graph in all blend

Table – 7: Engine Emission using Diesel fuel

100% Diesel with IP 190					
LOAD(kg)	**CO(%)**	**HC(ppm)**	**CO2(%)**	**O2(ppm)**	**NOX(ppm)**
1	0.05	26	1.7	18.08	91
2	0.05	30	1.7	17.87	107
3	0.05	23	1.8	17.74	111
4	0.05	32	2.1	17.26	140
5	0.06	34	2.2	17.01	154
6	0.06	35	2.4	16.69	181
7	0.06	41	2.7	16.26	215
8	0.04	26	3	16.12	309
9	0.04	35	3.1	15.74	348
10	0.06	42	3.4	15.31	351
11	0.05	43	4.4	14.09	373

Table – 8: Engine Emission using 10% WPO Diesel blended fuel

90% Diesel - 10% WPO with IP 190					
LOAD(kg)	**CO(%)**	**HC(ppm)**	**CO2(%)**	**O2(ppm)**	**NOX(ppm)**
1	0.04	39	1.6	17.98	92
2	0.05	29	1.8	17.76	114
3	0.06	41	1.9	17.57	118
4	0.05	34	2.1	17.22	154
5	0.05	42	2.3	16.83	193
6	0.05	35	2.6	16.52	238
7	0.05	32	2.4	16.78	250
8	0.04	35	2.2	16.97	275
9	0.04	41	2.7	16.12	297
10	0.05	34	2.9	16.14	312
11	0.04	39	3	16.09	346

Table – 9: Engine Emission using 20% WPO Diesel blended fuel

80% Diesel - 20% WPO with IP 190					
LOAD(kg)	CO(%)	HC(ppm)	CO2(%)	O2(ppm)	NOX(ppm)
1	0.04	36	1.6	18.17	95
2	0.05	35	1.7	17.91	109
3	0.05	43	1.8	17.74	134
4	0.05	38	2	17.48	144
5	0.05	42	2	17.42	167
6	0.05	35	2.5	16.75	220
7	0.06	47	2.6	16.45	238
8	0.06	45	2.8	16.25	276
9	0.05	42	3.2	15.82	325
10	0.05	53	3.1	15.8	334
11	0.05	56	3.3	15.5	410

Table – 10: Engine Emission using 30% WPO Diesel blended fuel

70% Diesel - 30% WPO with IP 190					
LOAD(kg)	CO(%)	HC(ppm)	CO2(%)	O2(ppm)	NOX(ppm)
1	0.04	37	1.5	18.23	93
2	0.05	42	1.7	17.91	108
3	0.05	42	1.8	17.71	124
4	0.05	36	2	17.52	145
5	0.05	48	2	17.32	169
6	0.05	52	2.1	17.11	181
7	0.04	50	2.3	16.94	214
8	0.05	54	2.5	16.44	245
9	0.04	39	2.5	16.68	249
10	0.04	40	2.6	16.42	281
11	0.04	43	2.8	16.23	304

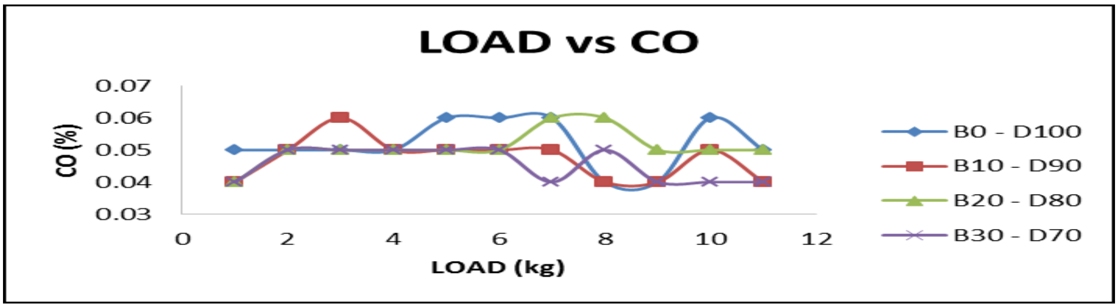

Figure – 6: Load vs CO graph in all blend

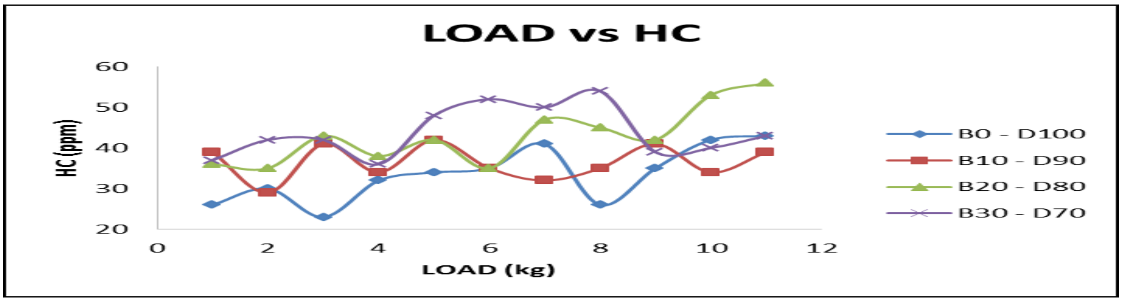

Figure – 7: Load vs HC graph in all blend

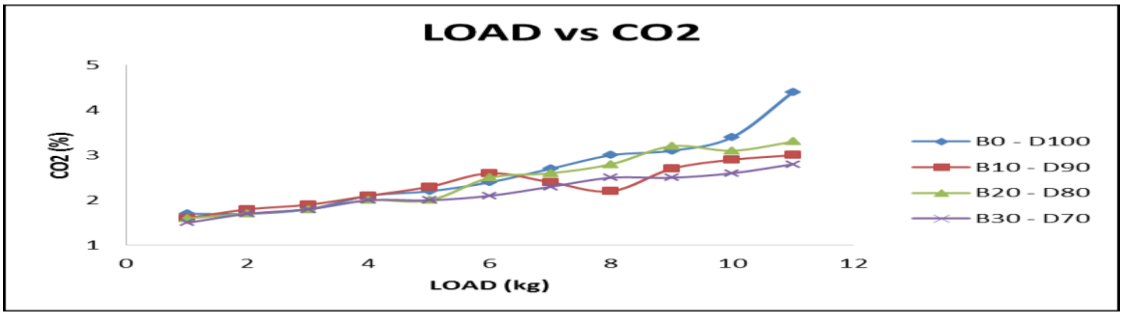

Figure – 8: Load vs CO_2 graph in all blend

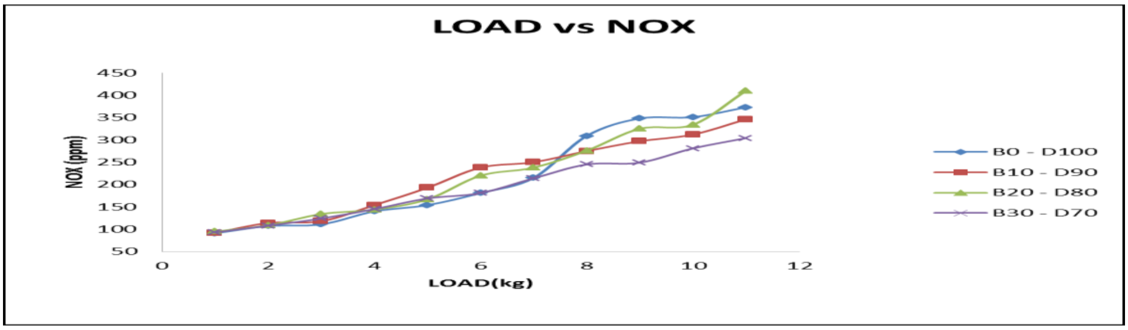

Figure – 9: Load vs NO_X graph in all blend

VII. Result And Discussion

Experimental results show that SFC decreases with increase in load while Mech. Effi. and BTE increases in all blend. Emission results shows that emission of HC, NOx and CO_2 increases with increase in load in all blend proportion. Results shows that 30% WPO diesel blend has lower SFC and higher BTE and ITE with compare to diesel. Also emission of NOx and CO_2 is less than diesel in 30% WPO diesel blend but HC emission increased by small level.

VIII. Conclusion

From experimental result it has been concluded that WPO can be used in CI engine with diesel. 30% WPO Diesel blend gives optimum result for performance and emission of diesel engine.

1) SFC decreases in 30% WPO Diesel blend with compare to diesel.
2) BTE and ITE increases in 30% WPO Diesel blend with compare to diesel.
3) Emission of CO, NOx and CO_2 decreases in 30% WPO Diesel blend with compare to diesel.
4) Emission of HC is slightly increases with compare to diesel.

Acknowledgements

We owe a great many thanks to a great many people who helped and supported us during this Research work. Especially we take an immense pleasure in thanking Mr. Samir Patel for providing us Plastic Pyrolysis Oil and related information selflessly. We wish to express a deep sense of gratitude to him for showing faith in us for this research work and we would expect the same in future if needed.Details of Plant producing Plastic Pyrolysis Oil is provided below.

Mr. Samir Patel, S. R. Industries, G-142, Growth Centre, Ricco Mawal, Abu Road, Rajasthan.

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Table – 11: Nomenclature

Abbreviation	Meaning
WPO	Waste plastic oil
SFC	Specific fuel consumption
BTE	Break thermal efficiency
ITE	Indicated thermal efficiency
Mech. Effi.	Mechanical efficiency
HC	Hydro carbon
CO	Carbon monoxide
NOx	Oxides of nitrogen
CO_2	Carbon dioxide
EGR	Exhaust gas recirculation