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PERFORMANCE CURVE AND EMISSION CHARACTERISTICS USING ALTERNATIVE FUELS ETHANOL AND BIODIESEL IN TURBOCHARGING DIESEL ENGINE

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ABSTRACT

We take Opportunity to present this project report synopsis of „Performance curve and Emission Characteristics using alternative fuels Ethanol and Biodiesel in turbocharging Diesel engine' and put before readers some useful information regarding our project. We have made since attempts and taken every engineer to present this matter in precise and compact form, the language being as simple as possible. We are sure that the information contained in this volume would certainly prove useful for better insight in the scope and dimension of this project in its true perspective. The task of completion of project through being difficult was made quit simple, interesting and successful. Drawn by a list of priorities like fast decreasing oil resources. We are going to use alternative fuels Ethanol and Biodiesel in turbocharging Diesel engine It will increase overall system efficiency and save considerable amount of money by decreasing of fuel consumption accordingly.

Keywords: Turbocharging diesel engine, Ethanol and Biodiesel, Brake power (B.P), ethanol-diesel blend (DE), ethanol-biodiesel-diesel blends (DBE).

INTRODUCTION

Need of Alternative Fuels

The main purpose of fuel is to store energy in a form that is stable and can be easily transported from the place of production to the end user. There is an immediate need of alternative clean fuels, which is abundantly available as well as has lower impact of pollution than the present fossil fuels & conserve conventional fuel. In this regards the various alternative fuels like CNG, LPG, Propane, Bio-diesel, Ethanol, Hydrogen, Fuel cells etc. will help in the reducing oil import bills of an oil-dependent country like India and also help in reducing environmental pollution. In the current market scenario, every nation in the world is busy finding the substitute for the conventional fuels diesel and petrol.

Ethanol as Automotive Fuel

Ethanol is most often used as a motor fuel, mainly as a bio-fuel additive for gasoline. World ethanol production for transport fuel tripled between 2000 and 2007 from 17 billion to more than 52 billion liters. Most cars on the road today in the U.S. can run on blends of up to 10% ethanol, and ethanol represented 10% of the U.S. gasoline fuel supply derived from domestic sources in 2011. Since 1976 the Brazilian government has made it mandatory to blend ethanol with gasoline, and since 2007 the legal blend is around 25% ethanol and 75% gasoline (E25). By December 2011 Brazil had a fleet of 14.8 million flex-fuel automobiles and light trucks and 1.5 million flex-fuel motorcycles that regularly use neat ethanol fuel (known as E100).

Bio-ethanol is a form of quasi-renewable energy that can be produced from agricultural feed-stocks. It can be made from very common crops such as sugar cane, potato, cassava and corn. There has been considerable debate about how useful bio-ethanol is in replacing gasoline. Concerns about its production and use relate to increased food prices due to the large amount of arable land required for crops, as well as the energy and pollution balance of the whole cycle of ethanol production, especially from corn. Recent developments with cellulosic ethanol production and commercialization may allay some of these concerns.

Ethanol is most commonly used to power automobiles, though it may be used to power other vehicles, such as farm tractors, boats and airplanes. Ethanol (E100) consumption in an engine is approximately 51% higher than for gasoline since the energy per unit volume of ethanol is 34% lower than for gasoline. The higher compression ratios in an ethanol-only engine allow for increased power output and better fuel economy than could be obtained with lower compression ratios. In general, ethanol-only engines are tuned to give slightly better power and torque output than gasoline-powered engines. In flexible fuel vehicles, the lower compression ratio requires tunings that give the same output when using either gasoline or hydrated ethanol. For maximum use of ethanol's benefits, a much higher compression ratio should be used. Current high compression neat ethanol engine designs are approximately 20 to 30% more fuel efficient than their gasoline-only counterparts. .

diesel-ethanol-biodiesel blends reduces NO_x, PM, Smoke with slight increment in HC emissions while keeping CO emissions at same level compared with diesel fuel.the alternative fuels,biodiesel and ethanol are the most widely studied biofuels for diesel engines and have received considerable attention in recent years [1–19]. Biodiesel has properties similar to those of traditional diesel such that it can be substituted for diesel fuel with no engine modification. Biodiesel has been recognized as an environment friendly alternative fuel for diesel engines.

Whenever we develop new fuels it is required test the fuel for its chemical and physical properties of it. To check the compatibility of the new fuel its chemical and physical properties are compared with base standard petroleum fuel. New fuel should satisfy the standard fuel properties to use it in engines for trouble free performance of that engine. In this chapter fuel blends are tested and properties are compared with base diesel fuel. Then these fuel blends are tested on the engine for performance and emission characteristics

EXPERIMENTAL SET-UP

The engine with dynamometer, fuel supply unit. This engine is loaded by eddy current dynamometer to find out brake torque. Engine and dynamometer is water cooled. Load and speed sensors are attached to the dynamometer.

Engine load is regulated by engine controller. Fuel consumption reading is recorded on the controller. Engine sensor output is also connected to the controller which shows reading on the controller. Emission analyzer is placed near to the controller. Cylinder calibration gases are connected to the emission analyzer unit. Air dryer connection is also given to the emission analyzer unit. Monitor which is placed on the emission unit shows the emission readings directly.

Table No. 1 Dynamometer Specifications

Dynamometer Model	AG 10
Type	Eddy Current Both directional
Water inlet	1.6 bar
Minimum	160 kPa
Pressure	23 lbf/in^2
Load	3.5kg
Torque	11.5 Nm
Hot coil voltage	Max. 60
Continuous current	5.0 amps
Cold resistance	9.8 ohms
Speed max.	10000rpm

Table No. 2 Engine Specifications

Engine power rating	3.5 KW at 1500 rpm
Engine Maximum Torque	28 N-m
Bore	87.5 mm
Stroke	110 mm
Number of Cylinders	1
Engine Displacement(cc)	661
Compression Ratio	17:1
Fuel	Diesel
Type	4 Stroke
Application	Agro, Industrial

Table No. 3 Emission Gas Analyser Specifications

Model	EXSA 1500
Make	Horiba , Japan
Analyser for NO_x	CLD -Chemiluminiscent Detector
Analyser for O_2	MPA-Magnetopneumatic analyser
Analyser for CO &CO_2	NDIR-Non dispersive infrared analyser
Analyser for THC	FID-flame ionisation detetor
Measurement	Diesel and Petrol Engines
Dynamometer arm length (mm):	185

Blending by magnetic stirring

This is the one of the easiest method to blend the fuels. Initially ethanol and diesel are mixed together in proportion and then flask is kept on the magnetic stirrer for five minutes. It consists of heating and stirring. After five minutes biodiesel is mixed with it in proportion and then all mixture is stirred once again for final blend. This procedure is repeated for all different blends.

Engine Testing Methodology

Existing diesel engine is the off road vehicle engine which is tested on 8 modes for performance and emission characteristics. Loading of the engine is done on constant speed 8 mode cycle. Initially engine is started and run at idle for some time to stabilize the engine. After stabilization engine is taken into full throttle position (FTP) and again it is kept as it is for some time for stabilization. Then engine is loaded with eddy current dynamometer to find out maximum torque and power for various speeds. Rated power and rated torque is noted down. Load values are dived in eight points considering maximum torque as 100%. Then remaining load values are found out by multiplying by 75%, 50%, 10% for maximum torque as well as maximum power.

For each load temperature, fuel consumption, speed are noted down. Two three such readings are taken and average readings are calculated. For new reading some time is given to stabilize the engine then the readings are taken. After conducting reading for single fuel engine is run with pure diesel to get the accurate results of fuel samples. Same procedure is repeated for each samples..

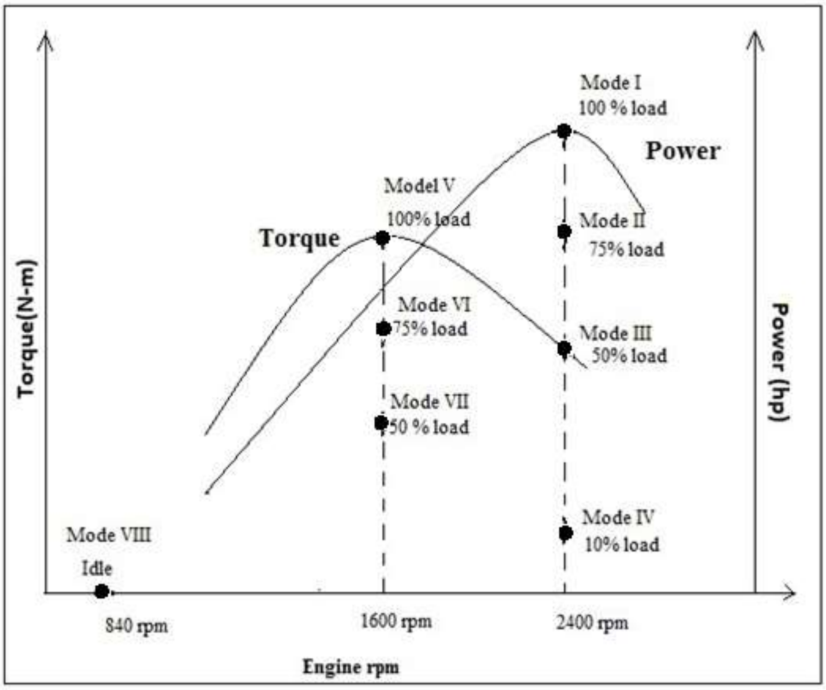

Fig. 1 Modes used for engine testing

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Table No. 4 Observation table for 8 Mode testing of Diesel engine using neat diesel fuel

Sr No.	Parameters	Units	1	2	3	4	5	6	7	8
	W.F.	-	0.15	0.15	0.15	0.1	0.1	0.1	0.1	0.15
1	Speed	Rpm	2410	2402	2396	2405	1701	1705	1690	840
2	Torque	Nm	171	133	89	18	208	155	107	-
3	Power	kW	43.1	33.45	22.33	4.53	37.05	27.67	18.93	-
4	Power	BHP	58.6	45.5	30.38	6.16	50.4	37.65	25.76	-
5	Exhaust temperature	ºC	468	427	353	208	500	467	410	170
6	Water inlet temperature	ºC	61.2	64.8	61.9	57.8	67.2	71.6	68.5	61.8
7	Oil temperature	ºC	101	99.5	96.3	91.8	100.1	98.3	95.4	90.5
8	SFC	$gm/hphr$	181.96	188.75	206.08	457.48	180.37	180.36	181.29	-
9	Air in temperature	ºC	29.9	31.4	31.7	31.4	31.8	32	32.6	32.3
10	Ambient temperature	ºC	33.5	32.3	32.3	32.4	32.3	32.8	33.6	34.1
11	Water temperature outlet	ºC	79.2	79	78.2	80	75	79.7	82.3	80.3
12	HC	ppm	48.36	62.12	81.73	103.3	47.23	50.04	107.51	157.37
13	CO	ppm	141.07	147.17	260.95	326.49	195	230.78	440.33	341.46
14	CO_2	%	9.8	8.38	6.47	2.36	9.38	8.1	6.24	1.43
15	NO_x	ppm	490	325.81	271.42	210.19	420.1	350.76	305.45	121.97
16	O_2	%	10.87	12.59	14.95	18.87	8.76	11.59	14.68	20.96

Table No. 5 Observation table for 8 Mode testing of Diesel engine using DB10 blend (90%Diesel+10% Biodiesel)

Sr No.	Parameters	Units	1	2	3	4	5	6	7	8
1	Speed	Rpm	2407	2401	2390	2410	1699	1705	1704	839
2	Torque	Nm	166	125	83	17	205	154	103	-
3	Power	kW	41.84	31.43	20.77	4.29	36.47	27.50	18.38	-
4	Power	BHP	56.92	42.76	28.25	5.83	49.62	37.41	25	-
5	Exhaust temperature(Te)	ºC	442	417	343	205	495	460	408	165
6	Water inlet temp(Twi)	ºC	60	63.2	60.5	56.7	66	69	67.5	60.8
7	Oil tempt(To)	ºC	99	98.2	95.1	90.5	100.1	97.7	94.4	89.3

8	SFC	$gm/hphr$	189.23	195.73	213.29	473.49	187.58	187.03	187.81	0
9	Air in temperature(Tai)	ºC	29.8	31.2	31.5	31.3	31.9	31.9	32.5	32.3
10	Ambient temperature(T)	ºC	33.5	32.4	32.2	32.3	32.4	32.8	33.6	32.3
11	Water temperature outlet(Two)	ºC	79.1	79	78.9	79.9	74.5	79.6	81.9	80.2
12	HC	Ppm	40	54	73	87	16	38	53	106
13	CO	Ppm	123.8	130.4	240.1	305.8	180.7	213.87	390.12	330.1
14	CO_2	%	10.6	8.47	6.62	3.67	10.02	9.14	7.62	1.44
15	NO_x	Ppm	528	475	280	218	507	501	306	120
16	O_2	%	8.62	10.15	12.10	16.93	7.84	9.11	11.32	20.08

Table No. 6 Observation table for 8 Mode testing of Diesel engine using DBE10 blend (80% Diesel+10% Ethanol+ 10% Biodiesel)

Sr No.	Parameters	Units	1	2	3	4	5	6	7	8
1	Speed	Rpm	2401	2395	2411	2403	1603	1610	1613	838
2	Torque	Nm	161	119	79	15	200	151	99	-
3	Power	kW	40.48	29.84	19.94	3.77	33.57	25.45	16.72	-
4	Power	BHP	55.07	40.6	27.12	5.13	45.67	34.62	22.74	-
5	Exhaust temperature	ºC	430	410	340	204	480	452	407	160
6	Water inlet temperature	ºC	60	63.1	60.4	56.6	64.2	68.4	67	60.8
7	Oil temperature	ºC	99	98.1	94.3	90.1	100	97	90	89.3
8	SFC	$gm/hphr$	201.97	209.43	229.77	507.8	198.40	197.4	202.13	-
9	Air In temperature	ºC	29.9	31.1	31.9	31.7	32	32.4	32.5	31
10	Ambient Temperature	ºC	33.4	32.1	32	32.6	32.1	32.7	32.8	34
11	Water temperature outlet	ºC	79	78.9	78.7	78.1	74.4	76.7	75.3	74
12	HC	Ppm	54.1	67.8	93.7	120.3	53.9	57.3	119.1	170.1
13	CO	Ppm	130.9	137.17	286.2	362.1	182.3	215.7	484.9	372.2
14	CO_2	%	10.7	8.59	6.71	3.87	10.97	9.54	7.8	1.56
15	NO_x	Ppm	420	370	222	186	543	375	254	74
16	O_2	%	8.19	9.62	11.70	16.29	7.4	8.89	11.05	18.8

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Table No.7 Observation table for 8 Mode testing of Diesel engine using DBE20 blend (70% Diesel+20% Ethanol+10% Biodiesel)

Sr No.	Parameters	Units	1	2	3	4	5	6	7	8
1	Speed	rpm	2396	2404	2415	2401	1630	1601	1610	837
2	Torque	Nm	159	120	80	16	195	147	98	-
3	Power	kW	39.9	30.21	20.23	4.02	33.28	24.64	16.52	-
4	Power	BHP	54.28	41.10	27.52	5.47	45.27	33.52	22.47	-
5	Exhaust temperature	ºC	425	407	335	201	471	443	401	159
6	Water inlet temp.	ºC	59.9	62.9	60.3	56.5	64.1	68	66.7	60.3
7	Oil temperature	ºC	98.2	97.7	94.1	90.0	99.9	96.3	89.9	89.1
8	SFC	$gm/hphr$	211.07	218.95	236.98	526.03	209.22	211.02	210.29	-
9	Air in temperature	ºC	29.8	31.2	32	31.6	31.9	32.3	32.4	31
10	Ambient temperature	ºC	33.4	32	31.9	32.3	32	32.5	32.7	34
11	Water temperature outlet	ºC	78	78.7	78.6	78	74.3	76.1	75.2	74
12	HC	ppm	57.6	74.5	101.9	134.1	56.4	61	133.3	204.6
13	CO	ppm	125.2	127.1	298.3	391.7	176.3	208	510.8	401.3
14	CO_2	%	8.31	7.47	5.1	3.38	9.1	8	6	1.1
15	NO_x	ppm	215	187	150	126	427	240	176	67
16	O_2	%	109	13.3	15.1	19.7	9.4	12.6	14.9	21.76

COMPARISION OF RESULTS AND DISCUSSION

To find out engine performance parameters there is requirement of engine observation data. This data is used to calculate different performance parameters like brake power, specific fuel consumption, emission etc. With the help of this performance parameters, the performance plots are plotted which gives characteristics of the engine under different load and speed conditions. In this chapter results are obtained for neat diesel fuel and ethanol blended fuel and comparison is made between two.

Effect of various blends on brake power

Brake power of diesel engine increases as load increases and this trend is similar for all blends. As shown in fig. 6.2. Brake power decreases slightly when blends are used because of lower heating value of ethanol and biodiesel. For neat diesel fuel maximum brake power is found to be 58.6 BHP. For blend DB10, it found to be 56.92. A drop of 2.86 percent is found using 10 percent biodiesel. For blend DBE10, there is drop of about 4.94 percent compared with neat diesel fuel; this is high due to lower calorific value of blend DBE10 than Blend DB10. For blend DBE20 reduction in brake power is found to be 7.37 percent, which is again lower than remaining two blends. Blend DBE20 has minimum calorific value amongst the all blends.

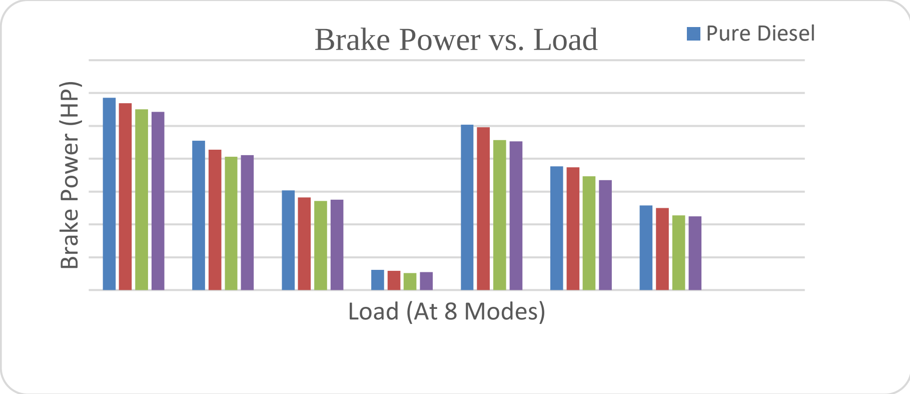

Fig.2 Brake power vs. Load comparison for various 8 loads using different blends

Effect of Various blends on BSFC

As shown in fig.3. Specific fuel consumption decreases as load increases and it is maximum at 10 percent load. This trend is similar for all blends. Fuel consumption increases as load increases. For neat diesel fuel maximum SFC is 457.48 gms/hp-hr at 10 percent load. For blend DB10 it is found to be 473.49 gms/hp-hr, increase in SFC of about 3.37 percent due to lower heating value of blend DB10 compared with neat diesel fuel. For blend DBE10 increase in SFC is 10 percent. For blend DBE20 increase in SFC is 13 percent which is largest amongst all blends due to lower calorific value of that blend. For medium load there is slightly difference in BSFC for all blends due to part load efficiency of diesel engine is high in this range.

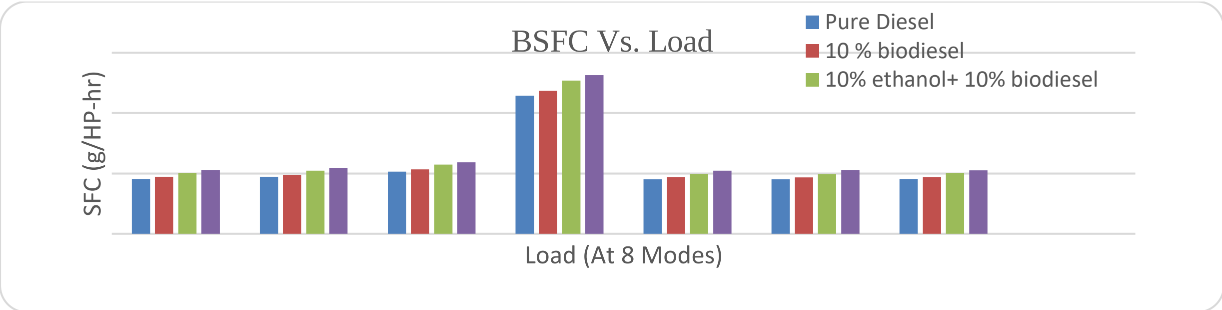

Fig. 3 BSFC vs. Load for various loads using different blends

Effect of various blends on CO emissions

As load increases CO emissions reduces for diesel fuel for all loads at 2400 rpm and 1600 rpm as shown in fig. 6.4 but for idle it is lower compared with 50 % load at 1600 rpm due to incomplete combustion. For blend DB10, CO emissions reduces by 12.24 % at maximum power and 7.33 % at maximum load compared with neat diesel fuel. For remaining 6 modes it reduces slightly. It is due to inbuilt oxygen content present in the biodiesel helps in complete combustion. For blend DBE10, CO emissions are increasing as load reduces compared with Blend A but it is lower than neat diesel fuel for first two modes. Similar is the case with other modes namely 5, 6, 7 and 8. For blend DBE20, CO emission are more (by 1.1%) compared with blend DB10 but lower (by 11.24 %and 13.63%) for first two modes compared with neat diesel fuel. This happens due to temperature lowering effect of ethanol in cylinder. This is dominant at light load than high load. At high load mixing is better, that's why CO emissions are high only at remaining two modes.

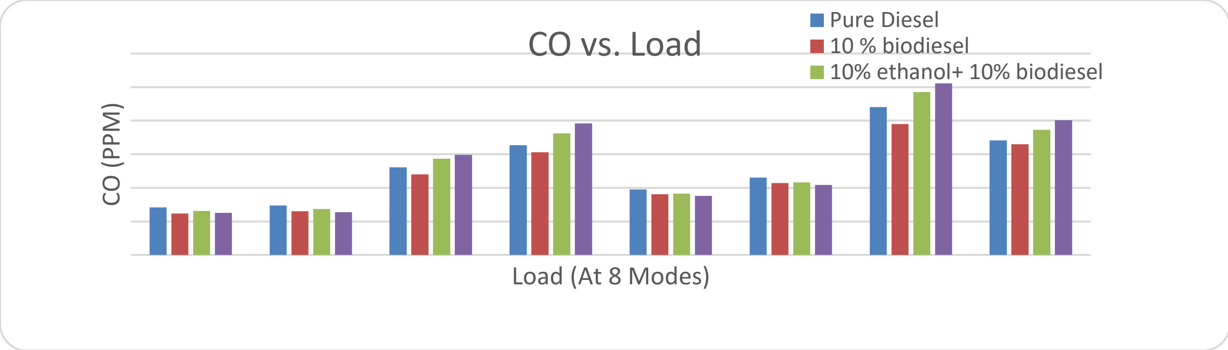

Fig. 4 CO vs. Load for various loads using different blends

Effect of various blends on CO_2 emissions

Fig. 5 shows the effect of various fuel blends on CO_2 emission at different loads. It is found that as load increases CO_2 emissions increases as more and more fuel burns at high load and complete combustion is achieved at high loads due to high temperature. This trend is similar for all fuel blends. For blend DB10, CO_2 emissions are higher at all modes and maximum increase is found out to be 35.69 % at mode number 4. CO_2 emissions are higher due to more complete combustion and more fuel consumption due to lower calorific value of biodiesel. For blend DBE10, CO_2 emissions are higher at all modes and maximum increase was 15.09 % at mode number 5. This blend has more CO_2 emissions amongst all blends. For blend DBE20, CO_2 emissions are lower at all modes except at mode number 4 due to incomplete combustion caused by high percentage of ethanol. The maximum reduction is 15.20 % at mode 1.

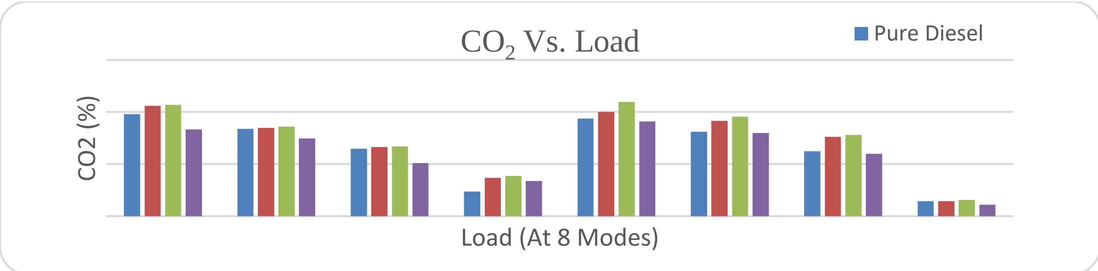

Fig.5 CO_2 vs. Load for various loads using different blends

Effect of various blends on NO_x emissions.

NO_x increases as load increases for diesel as well as for all blends as shown in fig.6.The factors which are responsible for NO_x emissions are temperature of combustion and oxygen content in the combustion. Out of which temperature is the dominant factor. As load increases combustion temperature increases which leads to high NO_x at high loads. For blend DB10 NO_x emissions increases at all modes except idle. Maximum increment of NO_x is found to be 30.14 % at mode number 6. The reason for increase in NO_x is due to oxygen content in the fuel blend. For Blend DBE10 NO_x emissions are seen to be reduced for all modes except mode number 5 and 6. Maximum reduction of NO_x is about 14.28 % at mode 1. For Blend DBE 20 NO_x emissions are reduced at all modes and maximum reduction is about 56.12 % compared with neat diesel fuel. It happened due to high ethanol percentage in the blend caused temperature lowering effect in the combustion. NO_x emission is complex phenomenon which is not only depend on fuel but also depend on loading conditions.

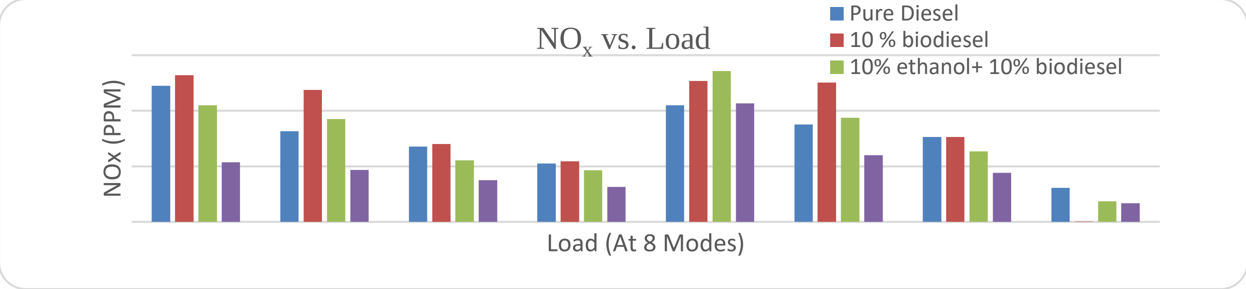

Fig.6 NO_x vs. Load for various loads using different blends

Effect of various blends on HC emissions.

HC emissions goes on reducing as load increases for diesel as well as for all blends as shown in fig.7 Trend for diesel and fuel blends are similar in nature. For blend DB10 HC emissions are lower at all 8 modes. Maximum reduction (by 50.70%) in HC is at seventh mode (50% load @1600 rpm).For high loads it is slightly reduced. Reduction in HC is due to high cetane number of biodiesel and complete combustion. For blend DBE10 HC emissions are slightly higher at all modes compared with neat diesel and blend DB10. Maximum increment is 14.13% at 10% load at 1600 rpm. For blend DBE20 HC emissions increases at all modes compared with all blends. Maximum increase in HC emission is found out to be 23.08 % at idle condition. HC emission are higher due to temperature lowering effect of ethanol and higher ignition delay of ethanol.

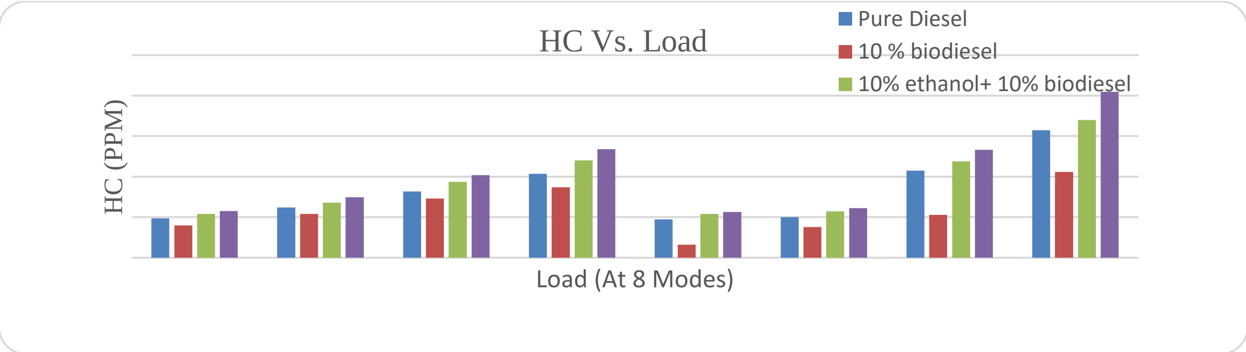

Fig.7 HC vs. *Load* for various loads using different blends

Overall emission results using weightage factor

Table No.8 Overall emissions for blends

	Neat Diesel	Blend DB10	Blend DBE10	Blend DBE20
HC (ppm)	83.245	60.35	92.915	104.27
CO (ppm)	252.8575	232.709	263.47	271.46
CO_2(ppm)	6.52	7.114	7.352	5.945
NO_x(ppm)	310.03	345.83	298.7	189.75

HC emissions are found to be increased by 10.40 % and 42.12 % for DBE10 and DBE20 respectively. CO emissions are slightly increased by 4.03 % for DBE10 blend and reduced slightly by 6.85 %. NO_x emissions are reduced slightly by 3.65 % for DBE10 blend but increased by 38.8 % for DBE20 blend. CO_2 emissions are increased by11.31 % for DBE10 blend and reduced by 8.8 % for DBE20 blend. For DB10 blend HC, CO, CO_2 reduced slightly but NO_x increased substantially.

CONCLUSION

Engine is tested for 8 modes cycle and effect of various blends on maximum brake power and maximum BSFC is as follows

1. Maximum Brake power for blend DB10, DBE10, DBE20 dropped by 2.86%, 4.94% and 7.37 % respectively compared with neat diesel fuel.

2. Maximum BSFC for blend DB10, DBE10, DBE20 increased by 3.37 %, 10%, 13 % respectively compared with neat diesel fuel.

Similarly emissions are measured for 8 modes for DB10, DBE10, DBE20 blends and percentage increment and reduction in emission with respect of diesel fuel are tabulated as follow

Table No. 9 Engine is tested for 8 modes cycle

	Mode	1	2	3	4	5	6	7	8
Blend A	HC	-17.28	-13.07	-10.68	-15.77	-66.12	-24.02	-50.70	-32.64
	CO	-12.75	-11.39	-7.99	-6.33	-7.33	-7.35	-11.40	-3.22
	CO_2	+7.5	+1.07	+2.26	+3.56	+6.38	+11.37	+18.11	+0.69
	NO_x	+7.19	+31.5	+3.21	+3.66	+17.15	+30.33	+0.32	+1.53
Blend B	HC	+10.60	+8.37	+12.77	+14.13	+12.37	+12.67	+9.73	+9.83
	CO	-7.2	-6.79	+8.8	+9.83	-6.51	-6.53	+9.27	+8.38
	CO_2	+8.41	+2.44	+3.57	+3.9	+14.5	+15.09	+20	+8.33
	NO_x	-14.28	+11.94	-18.08	-11.42	+22.65	+6.66	-1.67	-39.32
Blend C	HC	+16.04	+16.62	+19.79	+21.21	+16.26	+17.97	+19.35	+23.08
	CO	-11.25	-13.64	+12.52	+16.51	-9.58	-10.95	+13.8	+17.52
	CO_2	-15.2	-10.86	-21.17	+30.18	-2.98	-1.23	-3.85	-23.07
	NO_x	-56.12	-42.6	-44.74	-40.05	+1.62	-31.57	-42.38	-45.06

HC emissions are found to be increased by 10.40 % and 42.12 % for DBE10 and DBE20 respectively. CO emissions are slightly increased by 4.03 % for DBE10 blend and reduced slightly by 6.85 %. NO_x emissions are reduced slightly by 3.65 % for DBE10 blend but increased by 38.8 % for DBE20 blend. CO_2 emissions are increased by11.31 % for DBE10 blend and reduced by 8.8 % for DBE20 blend. For DB10 blend HC, CO, CO_2 reduced slightly but NO_x increased substantially.

Amongst the blends which are tested on the single cylinder DI diesel engine, blend DBE10 is found the best from performance and emission point of view because

- Blend DB10 has higher viscosity (856 kg/m^3) which do not satisfy the IS 1448 regulations. Because of high viscosity fuel injector and filters can choke-up. Power consumption increases as high power is required to pump the fuel due to heavy oil. NO_x emissions regulations are in narrow range than other emissions and biodiesel blend has high NO_x emission than other blends.
- Blend DBE10 has optimum viscosity and calorific value which gives slightly less brake torque and brake power. Slightly increase in BSFC is found. It has cetane index 42.04 which is satisfactory. It has optimum emission performance for HC, CO, NO_x and CO_2 emission.
- Blend DBE20 has lower calorific value amongst the all blends. It has lower cetane index (25.58) which is very low. It increases ignition delay and degrades performance of the engine. Drop in brake torque and and brake power is high. BSFC is high due to lower heating value of blend.

In general it can be said that diesel-ethanol-biodiesel blends reduces NO_x, PM, Smoke with slight increment in HC emissions while keeping CO emissions at same level compared with diesel fuel.

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