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COMPARATIVE PERFORMANCE AND EMISSION ANALYSIS OF A DUAL FUEL DIESEL ENGINE WITH AND WITHOUT TURBOCHARGER

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ABSTRACT

The present work describes an experimental investigation carried out on a twin cylinder direct injection dual fuel diesel engine fuelled with diesel, producer gas and blends of Karanja oil (10% and 20%) with and without turbo mode operations. This work particularly concentrates the effect of adding a turbocharger on the performance and emission analysis of the engine under variable loads and at an optimum gas flow rate. In conclusion, the study revealed that in turbo mode operation, the maximum thermal efficiency and pilot fuel saving of the engine is increased by 2.4% and 3% respectively, with reduced specific energy consumption and exhaust gas temperature compared to without turbo mode operation. Similarly, the emission parameters like hydrocarbon and carbon monoxide is reduced significantly whereas, nitrogen oxide and carbon dioxide emissions are increased slightly compared to without turbo mode operation for all test fuels under all test conditions. Again, it is observed that with increase in blend percentage in diesel, the emission parameters decreases compared to diesel in both test modes at all test conditions.

***Keywords**:* Turbocharger; Producer gas; Dual fuel; Karanja oil; Performance; Twin cylinder

1. INTRODUCTION

Due to increase in environmental pollution and crisis of crude oil, it is essential to use alternative fuels for diesel engine. Producer gas and vegetable oil bends are two potential alternative fuels for diesel engine. For further increasing its efficiency and reducing emissions, various studies have been performed. It is confirmed that by increasing the combustion process, engine efficiency must be increased and emission must be decreased. To improve this combustion process, some of the methods are; use of turbocharger, improved injection process and improved combustion chamber design [1]. Various researchers in their studies reported different alternative fuels or fuel blends to improve combustion process and reduce exhaust emission of diesel engine [2, 3]. The four different methods of using alternative fuels in diesel engine are blending, fumigation, dual fueling and direct using [4, 3, 5]. Wang et al. [6] performed an experiment using different vegetable oil blends with diesel and concluded that lower NO_x and a small change in CO emission as compared to diesel. The main objective of using dual fuel engine is to reduce NO_x and particulate matter (PM). Simultaneously, it is difficult to reduce both NO_x and smoke in case of diesel engine due to the trade-off curve between NO_x and smoke. Woody producer gas can be used as an alternative potential fuel for diesel engine due to their eco-friendly nature [7, 8].

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Turbocharger is a pressure boosting device generally used for improving the combustion performance of the engine by providing enough air at inlet. It consists of turbine and compressor which are coupled together [9]. The objective of using turbocharger is to increase the volumetric efficiency of air by utilizing the exhaust energy of the engine exhaust. Sahin et al. [1] performed an experiment in an IDI turbocharged diesel engine using gasoline fumigation and stated that efficiency increased and brake specific fuel consumption reduced approximately 5%. Rakopoulos *et al.* [10] performed an experiment in a turbocharged diesel engine using diesel, blend of bio-diesel and n-butanol with diesel and concluded that smoke opacity increased 40% for biodiesel blend and decreased 69% in case of n-butanol blend. However, NO emission for both blends increased as compared to neat diesel fuel. Gharehgani and Yusaf [11] carried out an experiment using a turbo- charged spark ignition engine and reported that the maximum thermal efficiency was increased by 4% at 2500 rpm over a natural aspirated engine. Shirk *et al*. [12] examined the effect of H_2 addition on the exhaust emissions of a turbocharged four-cylinder diesel engine and found that substitution of 5% and 10% diesel by hydrogen slightly reduced the NO_x emission, but substantially increased the formation of NO_2 emission. Zamboni and Capobianco [13] carried out an experiment by using low and high pressure exhaust gas recirculation (EGR) on pollutant emission of an automotive turbocharged diesel engine. They concluded that low pressure EGR circuit proved to be potential enhancer of NO_x emission.

2. TEST ENGINE SETUP AND PROCEDURE

The experimental setup consists of a twin cylinder, 4-stroke water cooled, direct injection diesel engine coupled with electrical generator and bulb loading devices. The experiment is carried out in two different test arrangements of the engine. The test-1 is carried out at normal mode (without turbo) by using the test fuels such as fossil diesel(FD), K10 and K20 with producer gas in dual fuel mode at an optimum gas flow rate of 21.49 kg/hr under different loads of 0, 2, 4, 6, 8 and 10 kW respectively. The properties of test fuels (gas and liquid) are shown in Table-1and 2 respectively.

Table 1. Composition and properties of producer gas.

Composition	**CO–19 ± 3%, CO_2–10 ± 3%, N_2–50% H_2–18 ± 3%, CH_4– up to 3%**
Density	1.287 kg/m^3
Calorific value	3771 kJ/kg
Octane number	100 –105
Laminar burning velocity	0.5 ± 0.05 m/s
Stoichiometric air/fuel ratio	1.12

Table 2. Estimated properties of test fuels

Properties	**Diesel**	**Karanja oil**	**K10**	**K20**	**ASTM Methods**
Density at 25^{o}C(kg/m^3)	825	925	832	837	D 1298
Kinematic viscosity At 40^{o}C (cSt.)	2.76	28.69	3.7	4.36	D 445
Acid value(mg KOH/g)	-	30.76	-	-	D 664
FFA (mg KOH/g)	-	15.41	-	-	D 664
Calorific value (MJ/kg)	42.5	34.7	41.72	40.91	D 240
Cetane number	47	32.33	-	-	D 613
Flash point (^{o}C)	73	219	89	109	D 93
Fire point (^{o}C)	103	235	119	135	D 93
Cloud point (^{o}C)	-12	3.5	- 4	-6	D2500
Pour point (^{o}C)	-16	-3	-10	-14	D97

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Test-2 is performed under same engine operating conditions after a proper modification of the above engine into turbocharged mode with necessary retrofits arrangements. During test-1, the producer gas generated at high temperature in the reactor enters into the gas cooler to get the desired working temperature. At the outlet of the filter pipe, a mechanical valve is fitted to control the gas flow rate manually. For gas flow measurement, a calibrated orifice meter along with a manometer is connected to gas surge tank. The producer gas and air are mixed in the intake pipe and then the mixture enters into the engine cylinder. The photograph of experimental setup under turbo mode operation is shown in Figure 1.

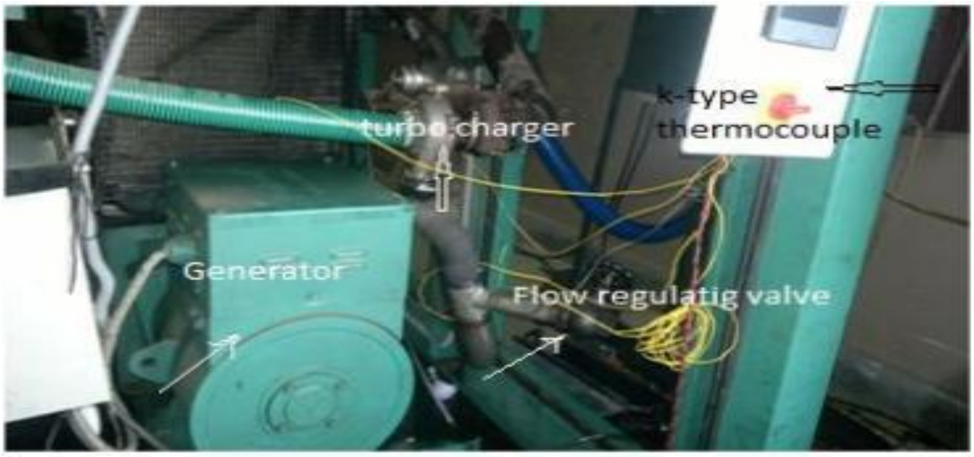

Fig. 1. Photographic view of engine setup under turbo mode operation

During test-2, for smooth flow of producer gas into the engine intake manifold, a flow regulating valve and a y-shaped gas induction system is fitted at their respective position. The engine is always operated at its rated speed of 1500 rpm, injection pressure of 220 bar and injection timing of 23^o before top dead centre. The specifications of the test engine and the gasifier are shown in Table 3 and 4 respectively.

Table 3. Test engine specifications

Make	**Prakash Diesel Pvt. Ltd. Agra**
Rated horse power	14 Hp
No of cylinder	Two
No of stroke	4-stroke
Rpm	1500
Compression ratio	16.5:1
Bore diameter	114 mm
Stroke length	110 mm
Injection pressure	220 bar
Injection timing	23˚ BTDC
Alternator	10.3 kW, directly coupled to engine 15 KVA, 21 amp, 3-phase, 415 volt

Table 4. Specification of down draft gasifier

Supplier	Ankur Scientific Energy Technology Pvt. Ltd., Baroda
Model	WBG-10 in scrubbed, clean gas model
Gasifier type	Down draft
Rated gas flow	25 NM^3/hr.
Average gas calorific value	1000 Kcal/ Nm^3
Gasification temperature	1050^{o}C– 1100^{o}C
Fuel storage capacity	100 kg
Permissible moisture	Less than 20% (wet basis)
Rated hourly consumption	8-9 kg
Ash removal	Manually, dry ash discharge

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With and without turbo (natural aspirated) mode is indicated as (WT) and (NA) respectively, in the figures. The loads are given in terms of brake power (bp). The AVL make 5-gas analyzer (model no. AVL Digas 444) is used for measurement of emission parameters

3. RESULT AND DISCUSSION (PERFORMANCE PARAMETERS)

3. 1. *Brake Specific Energy Consumption (BSEC)*

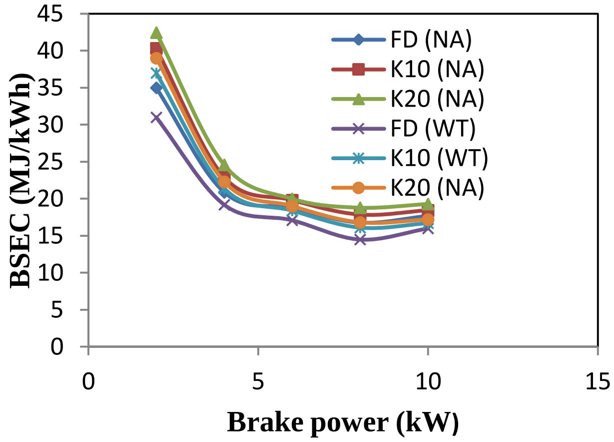

Fig. 2. Variation of BSEC with BP

Figure 2 shows the effect of brake power on BSEC for all test fuels with and without turbocharger. It is seen that the BSEC in case of turbo mode operation is significantly lower than the natural aspirated mode for all test fuels under all engine operating conditions. The reason may be due to complete and smooth combustion of cylinder charge as a result of supply of enough air by turbocharger. Again, with increase in load up to 8 kW, BSEC decreases gradually after that it increases for all test fuels in both test modes. The percentage decrease in BSEC in turbo mode operation of FD, K10 and K20 are 10.8%, 9.51% and 9.45% respectively, as compared to without turbo mode at 8 kW load. Furthermore, both the blended fuels show slightly higher values of brake specific energy consumption compared to fossil diesel in both modes of operations. This is due to lower calorific value and higher viscosity of blended fuels compared to fossil diesel.

3. 2. Brake Thermal Efficiency (BTE)

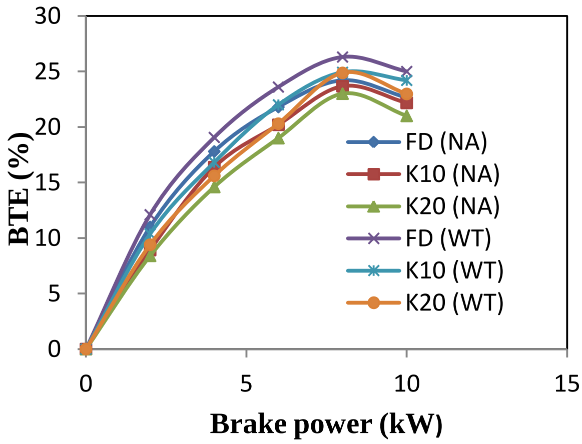

Fig. 3. Variation of BTE with BP

Figure 3 shows that with increase in load up to 8 kW, the BTE increases gradually after that it decreases for all test fuels under both the modes. The reason being; up to 8 kW load an efficient combustion of fuels takes place due to increase in combustion temperature whereas, at maximum load, it decreases due to poor combustion as a result of rich mixture. However, the BTE values in turbo mode operation are higher than natural aspirated mode for all test fuels. This could be attributed to efficient combustion inside the cylinder due to better chemical reaction of air with fuel as a result of supply of more fresh air by turbocharger. The maximum increase in BTE values of FD, K10 and K20 in turbocharged mode at 8 kW load are 2.4%, 2.1% and 2.04% respectively, compared to natural aspirated mode. Again, both blended fuels show slightly lower BTE compared to fossil diesel under both test modes due to lower cetane number and poor atomization characteristics of blended fuels.

3.4. Pilot fuel savings

The liquid (pilot) fuel savings in turbo mode operation is calculated as,

% liquid (pilot) fuel savings =

$$\frac{Liquid\ \ fuel\ consumption\ in\ without\ turbo\ mode - liquidfuel\ consumption\ in\ turbo\ mode}{liquid\ \ fuel\ consumption\ in\ without\ turbo\ mode} \times 100$$

The effect of brake power and gas flow rates on liquid (pilot) fuel savings for both modes of operation for all test fuels are shown in Figure 4.

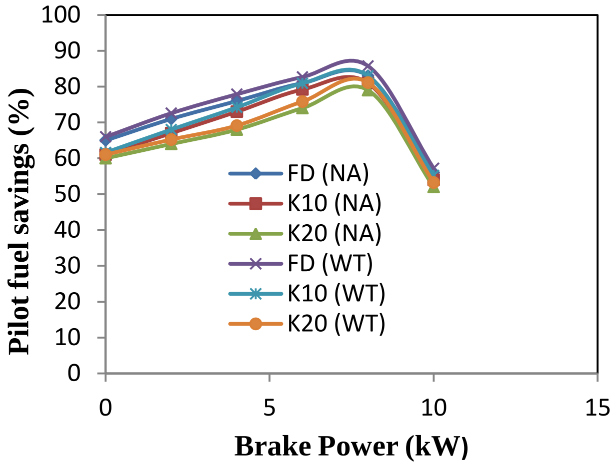

Fig. 4. Variation of pilot fuel savings with BP

It is found that the liquid (pilot) fuel savings in turbo mode of all test fuels are higher than their natural aspirated mode at all load condition. This may be due to complete burning of producer gas with pilot fuels as a result of enough air and better reaction of pilot fuels with gas. The highest liquid (pilot) fuel saving obtained in turbo mode operation of diesel is about 86% compared to 83% in natural aspirated mode at 8 kW load. It is also observed that the liquid (pilot) fuel saving percentage is decreased slightly in case of blended fuels. This is due to the lower calorific value and poor atomization of the vegetable oil.

3. 5. Carbon Monoxide (CO) emission

The variations of CO emissions with loads for both modes are shown in Figure 5. It is found that a significant reduction of CO emission is achieved in turbo mode operation compared to natural aspirated mode for all test fuels under all test conditions. The percentage decrease in CO emissions in case of turbo mode operation of FD, K10 and K20 are 16.3%, 18% and 15.21% respectively, compared to natural aspirated mode at optimum load condition. The reason being; turbocharger provides more oxygen at intake, which leads to better combustion and more oxidation of CO indicating lower CO emission. Again, K10 shows lower CO emission compared to K20 and diesel in both test modes.

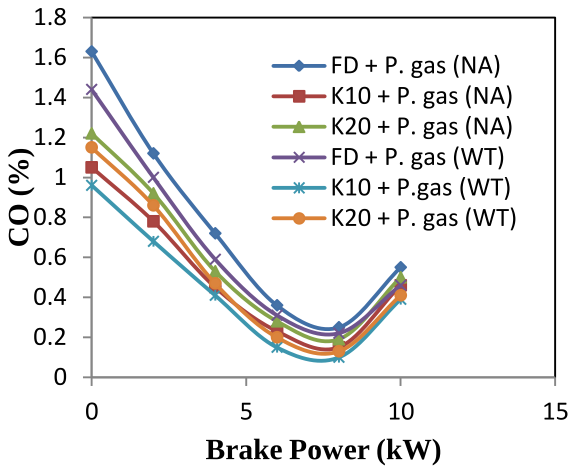

Fig.5. Variation of CO emission with BP.

3. 6. Hydrocarbon (HC) emission

Figure 6 indicates that HC emission of all test fuels in case of turbo mode operation is lower than natural aspirated mode.

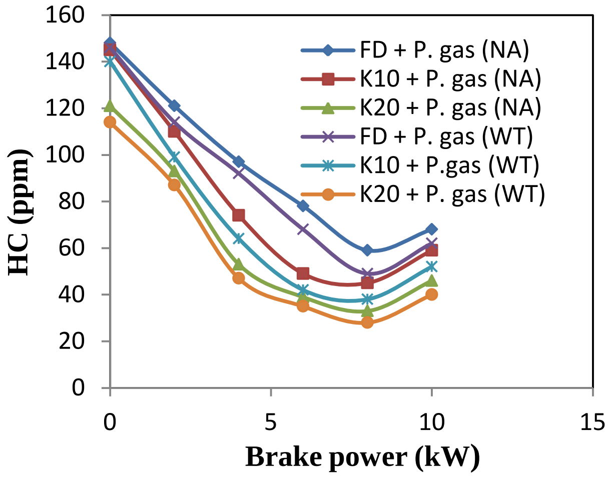

Fig. 6. Variation of HC emission with BP.

This may be due to smooth and efficient combustion of lean mixture as a result of higher quantity of air provided by turbocharger. The percentage decreases in HC emissions in case of turbo mode operation of FD, K10 and K20 are 10.8%, 11.86% and 13.1% respectively, compared to natural aspirated mode at 8 kW load. Again, it is observed that HC emission gets reduced considerably in both blended fuels compared to diesel at all test conditions. This is because of better combustion of blended fuels compared to diesel due to the presence of inherent oxygen in neat oil blends.

3.7. Nitrogen Oxide (NO) emission

The variations of NO emissions at different loads for all test fuels under both test modes are shown in Figure 7. It is observed that with increase in load, NO emission increases gradually for all test fuels and test modes. The reason being with increase in load, energy input increases, resulting in higher combustion temperature leading to formation of higher NO emission. However, there is a slightly increase in NO emission in turbocharged mode compared to natural aspirated mode. This may be due to availability of oxygen and higher peak combustion

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temperature in turbo mode. Again, with increase in blend percentage in diesel, the NO emission decreases under all load conditions.

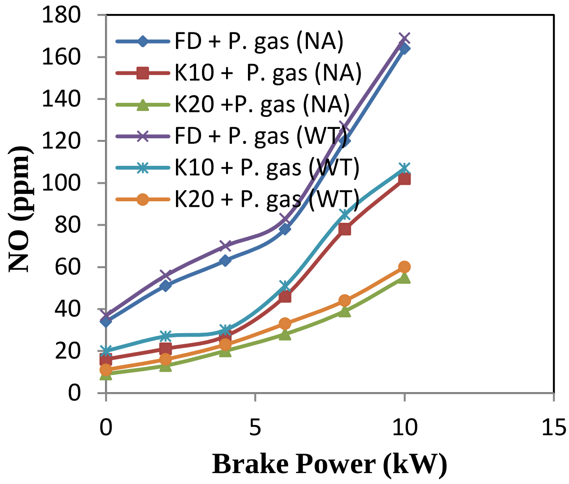

Fig.7. Variation of NO emission with BP.

This could be attributed to lower peak combustion temperature as a result of lower energy released during pre-mixed combustion phase due to larger droplet size of blended fuels compared to diesel [14].

4. CONCLUSIONS

The following conclusions are drawn based on experimental results obtained while operating a twin cylinder dual fuel diesel engine with and without turbo mode fuelled with fossil diesel, K10 and K20 under different load conditions.

1) The addition of turbocharger to the existing engine, the maximum brake thermal efficiency and pilot fuel saving of the engine increases by 2.4% and 3% respectively, compared to natural aspirated mode.
2) The BSEC and EGT decreases in turbo mode compared to without turbo mode under all test conditions.
3) Again, blended fuels show lower performance and better emissions compared to diesel in both modes of operations.
4) The NO emissions for all test fuels in turbo mode operation increases slightly compared to their natural aspirated mode. Both the blended fuels show better control of NO emissions compared to base line diesel under all test conditions.
5) The other emission parameters like CO and HC values of all test fuels in turbo mode operations are lower than their natural aspirated mode under all test conditions.

Finally, it is seen that without any processing of neat Karanja oil it can be blended up to 20% for better emission as compared to diesel at an optimum producer gas flow rate of 21.49 kg/hr.

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