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Experimental Studies on The Performance and Emission Characteristics of A Turbocharger Coupled Multi Cylinder Diesel Engine

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Abstract

An experimental investigation was carried out to evaluate the performance and emission characteristics of a turbocharger coupled multi cylinder diesel engine. Turbocharger is an equipment which helps to counter and reduce pollution. It's fitted to the diesel engine. The exhaust gases coming out from the engine are utilized in running the turbine and after that the exhaust gas escapes to the atmosphere. The turbine is connected to a compressor; combustion takes place by the air present inside the engine at initial condition. As the exhaust gas comes out after combustion, it sets the turbocharger in motion and thus the compressor. The compressor supplies additional air for ignition which will result in complete combustion. Thus it reduces the polluting effect of the exhaust gases. The work carried out of this project to give a detailed analysis of the turbocharger and to check the performance variation in a 4-stroke multi cylinder diesel engine with and without the turbocharger. Tests were conducted in a suitably instrumented, four stroke, multi cylinder, water cooled diesel engine at five different loads 0, 25, 50, 75 and 85% of rated load in diesel fuel. While the performance of the engine was evaluated using brake thermal efficiency, brake specific fuel consumption, mechanical efficiency, thermal efficiency and exhaust emissions were studied. The emission levels of NO_X, HC, CO and CO_2 were used for emission characteristics. The investigation indicates that the implementation of turbocharger offers high efficiency compared to without implementation and reduces the engine noise also. CO emissions and smoke capacity decreased significantly while NO_X emissions decreased marginally.

Keywords: Diesel Engine; Turbocharger; Performance; Efficiency; Emission.

Nomenclature:

Symbol	Meaning	Unit
BP	Brake Power	KW
SFC	Specific Fuel Consumption	Kg/Kw hr
BTE	Brake Thermal Efficiency	%
VE	Volumetric Efficiency	%
ME	Mechanical Efficiency	%
CO	Carbon Monoxide	%
CO_2	Carbon Dioxide	%
HC	Hydro Carbon	%
NO_X	Nitrogen Oxides	%

Introduction

The direction or goal towards which the present day automobile engineers are steered is to obtain more power and more fuel economy from an automobile engine without increasing the parameters of the engine viz., speed, volume and etc. But such efforts will lead to increase in overall engine size and cost. The concept of supercharging i.e. instead of charging air or air fuel mixture into the combustion chamber of the engine at atmospheric pressure, it is charged at some pressure and temperature well above the atmospheric conditions was first applied by an American Engineer CHADWICK in 1906. A supercharger is a positive displacement rotary or reciprocating pump or a rotary compressor or blower. If the supercharger is driven by exhaust gas or air, then it is called as turbocharger.

The turbocharger was invented by a Swiss Engineer BUTCHI in 1906 and has been seen from time to time in various versions ever since. However, it is only in the past two decades that it has been developed to such a degree of perfection, reliability and performance that it is now being fitted to a continuously increasing percentage of new IC engines. The turbocharger is essentially an exhaust driven supercharger, its primary purpose being to pressurize the intake air, so increasing the quantity of air entering to the engine cylinders on the suction stroke, and allowing more fuel to be burnt effectively. In this way, the torque and power output of an engine can be increased by upto 40 per cent by the addition of a turbocharger. For aircraft engine it is a means to high power output for take-off and to offset the rare atmospheric changes at high altitudes. It is especially used for diesel engines because turbo charging has the better efficiency on the compression ignition engines only.

Turbo charging of a petrol engine which has the optimum compression ratio for the available fuel, causes combustion knock and necessitates lowering of compression ratio, enriching the mixture, or increasing the octane number of the fuel. The increase in indicated specific fuel consumption is 7 percent for a 15 percent gain in specific output. In actual case, the inlet temperature rises as the inlet pressure is increased. It is evident that the supercharging of spark ignition engines requires a compromise between power output and efficiency.

Exhaust gas emission from diesel engine are more smoke, oxide of nitrogen and unburnt hydrocarbon. Therefore world facing very serious problem of air pollution. The air pollutants such as dust, gas fumes, mist odour, smoke or vapor which causes injuries to human, plant, animal like. The main pollutants can contributed by the internal combustion engines were carbon monoxide (CO), carbon dioxide (CO_2) unburned hydrocarbons (HC), oxide of nitrogen (NO_X), smoke density and particulate. Hence it is necessary to control the emission from I.C. Engine. In the present investigation, has been made to study performance and exhaust emission characteristics of a diesel engine with the use of turbocharger [1].

Qiqing Jiang et al [2] conducted performance and emissions tests on a four cylinder turbocharged diesel engine. They suggested that fumigation may have a potential as an emission control technique in diesel engines to reduce NO_X.

A.R.Schroeder et al [3] conducted tests on a multi cylinder, turbocharged diesel engine fumigated with methanol by changing the diesel injection timing. Tests results indicated that advancing the injection timing decreased CO and HC levels in the exhaust and that the increase in NO levels due to advances in diesel timing was offset by the decrease in NO due to ethanol addition.

A.R.Patil et al [4] Reduction of exhaust emissions is extremely important for diesel engine development in view of increasing concern regarding environmental protection and stringent exhaust gas regulations. The diesel fuel properties have become even more stringent controlling diesel exhaust emissions through fuel modification seems to be promising because it would affect both the new and old engines. Modification of diesel fuel to reduce exhaust emission can be performed by increasing the Cetane number, reducing fuel sulphur, reducing aromatic content, increasing fuel volatility and decreasing the fuel density to have the compromise between engine performance and engine out emissions, one such change has been the possibility of using diesel fuels with oxygenates.

Experimental Setup

Engine Experimental Setup

The engine shown in Fig. 2.1 is a four stroke, vertical, multi cylinder, water cooled and constant speed diesel engine which is coupled to rope brake dynamometer arrangement to absorb the power produced by the engine. The engine crank started. Necessary dead weights and spring balance are included to apply load on brake drum. Suitable cooling water arrangement for the brake drum is provided. Separate cooling water lines fitted with temperature measuring thermocouples are provided for engine cooling. A measuring system for fuel consumption consisting of a fuel tank, burette, and a 3- way cock mounted on stand and stop watch are provided. Air intake is measured using an air tank fitted with an orifice meter and a water U- tube differential manometer. Also digital temperature indicator with selector switch for temperature measurement and a digital rpm indicator for speed measurement are provided on the panel board. A governor is provided to maintain the constant speed.

Figure 2.1: Multi cylinder 4 Stroke Diesel Engine

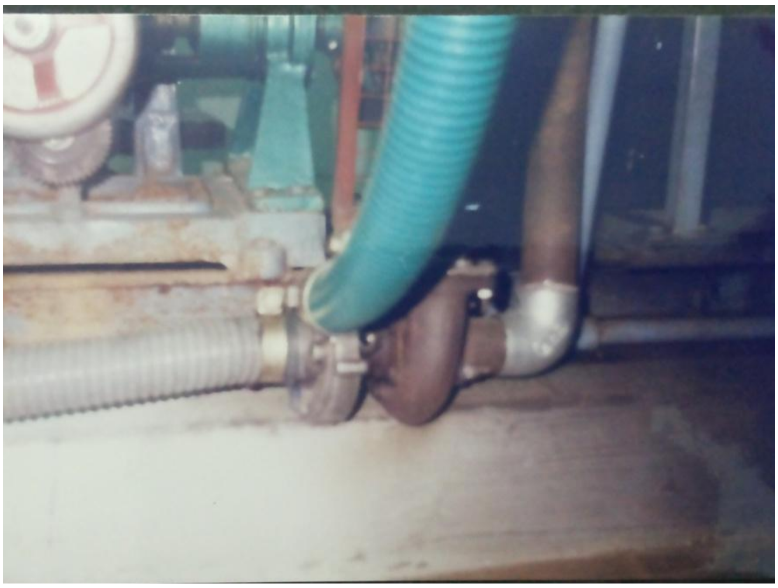

Figure 2.2: Incorporation of Turbocharger on 4 Stroke Multi Cylinder Diesel Engine

Table 2.1: Specifications of the Test Engine	
Particulars	**Specifications**
Make	National
Type	Vertical, Four strokes, Multi Cylinder, Diesel Engine, Water Cooled
Bore	80 mm
Stroke	110 mm
Compression ratio	15:1
Max. Power	11 KW
Speed	1500 rpm
Lubrication Oil	SAE 30
Specific Fuel Consumption	250 g/KW h
Calorific Value	42000 KJ/Kg K

Turbocharger

The turbocharger shown in Fig. 2.2. The turbocharger is made up of three sections, i) The centre bearing housing, ii) The turbine housing and iii) The compressor housing. The centre bearing housing contains two plain bearings, piston-ring type seals, retainers and a thrust bearing. There are also passages for supply and dumping of oil to and from the housing. The turbine wheel turns in the turbine housing and is usually integral with the turbine shaft, which is carried in the plain bearings in the bearing housing. The compressor wheel, which is fitted to the opposite end of the turbine shaft forming a combined rotating assembly, turns in the compressor housing. Turbocharger rotational speeds can reach 120,000 rpm on some small high performance engines.

Table 2.2: Specifications of the Turbocharger	
Particulars	**Specifications**
Make	K.K.K. (TELCO)
Type	Constant Pressure

Description of The Experimental Procedure

The experiments were carried out on water cooed multi cylinder four strokes direct injection constant speed maintained at 1500 rpm vertical diesel engine was use for investigation of performance test and exhaust evaluation. Experiments were carried out on standard base engine and along with the turbocharger. The engine was coupled to a rope brake drum dynamometer was used to measure the power output at constant engine speed. The engine is instrumented to measured parameters like fuel consumption, load, speed of engine, cooling water temperature, inlet air and exhaust gas temperature etc. The NOx level is measured by using NOx analyzer. Smoke is measured by using smoke density meter. Experiments were conducted at constant speed with various loads to determine the performance and emission parameters.

Tests were conducted by running the engine with diesel at its rated speed and at five torque levels corresponding to 0, 25, 50, 75 and 85 % of rated load. In each test the volume flow rate of diesel, load, mass flow rate of coolant water, engine speed, engine exhaust air temperature and the constituents of exhaust emission such as NO_X, HC, CO and CO_2 were measured at steady states. Each test was repeated thrice and the average of the measured values was taken for evaluation of engine performance and emission characteristics.

Results and Discussions

Specific Fuel Consumption

The variation of specific fuel consumption was higher at no load than full load conditions which shown in Fig. 4.1. for without coupled turbocharger and with coupled turbocharger. The SFC of with coupled turbocharger has shown little improvement fuel consumption at almost all load conditions.

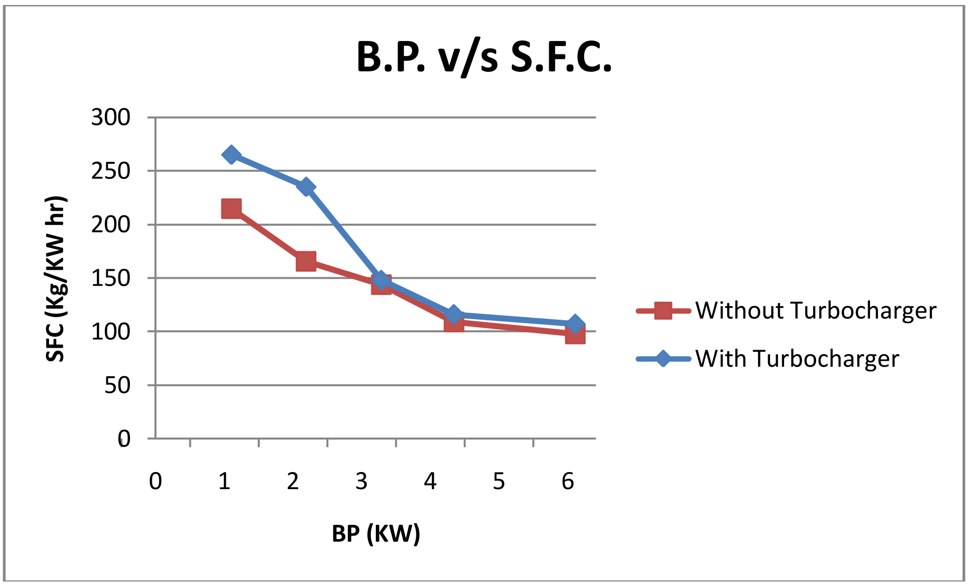

Figure 4.1: Brake Power v/s Specific Fuel Consumption

Brake Mean Effective Pressure:

The brake mean effective pressure is also nearly same at all load condition in coupled turbocharger engine when compared to base engine. The Brake mean effective pressure for both the case as shown in Fig. 4.2.

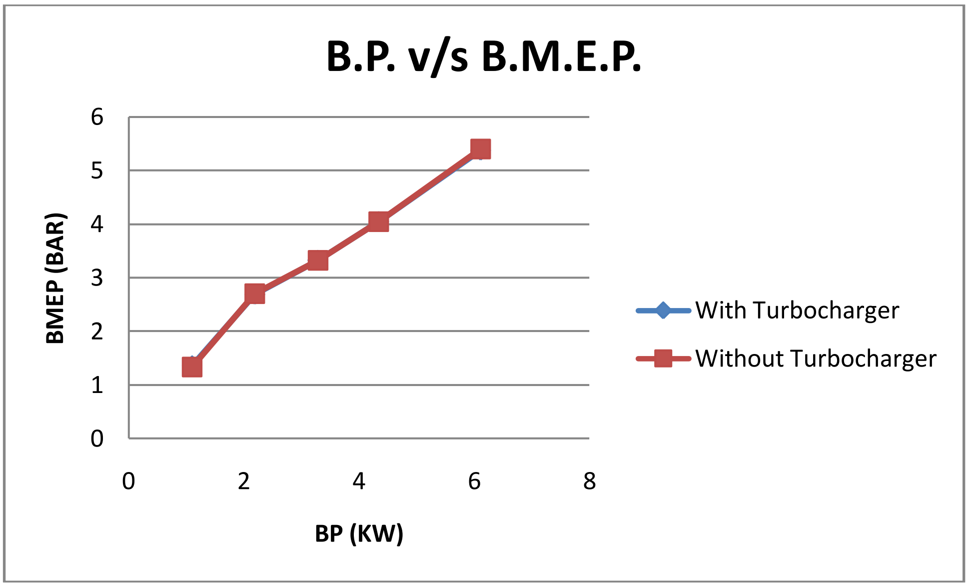

Figure 4.2: Brake Power v/s Brake Mean Effective Pressure

Brake Thermal Efficiency
It is seen that at all load conditions the improvement of brake thermal efficiency in turbocharged engine than the ordinary engine. At no load conditions BTE was decrease than it was increases in both types of cases. The variation of brake thermal efficiency in turbocharger coupled engine and without coupled engine as shown in Fig. 4.3.

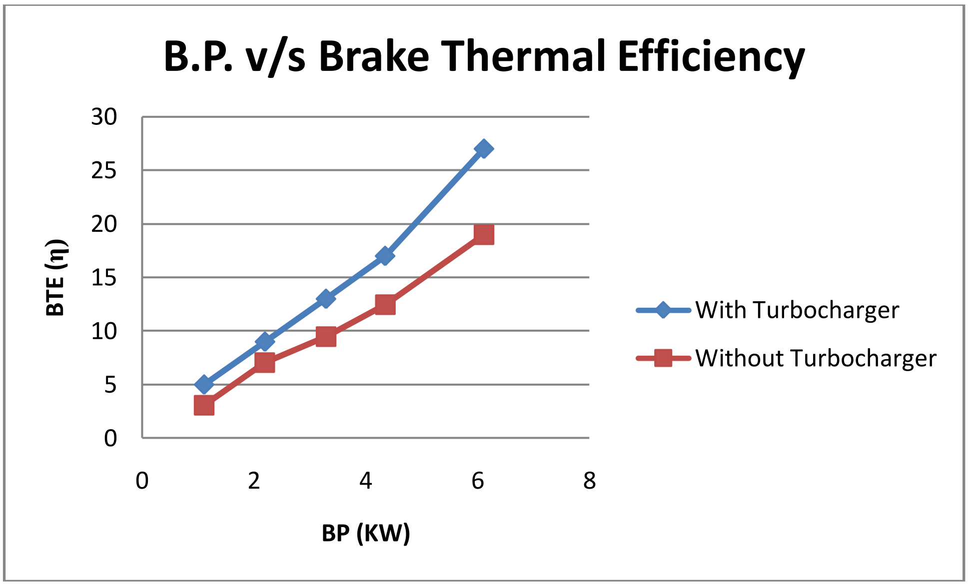

Figure 4.3: Brake Power v/s Brake Thermal Efficiency

Volumetric Efficiency

It is seen that there is slight improvement in volumetric efficiency in turbocharger coupled engine. The variation of volumetric efficiency was higher at no load than full load conditions which shown in Fig. 4.4.

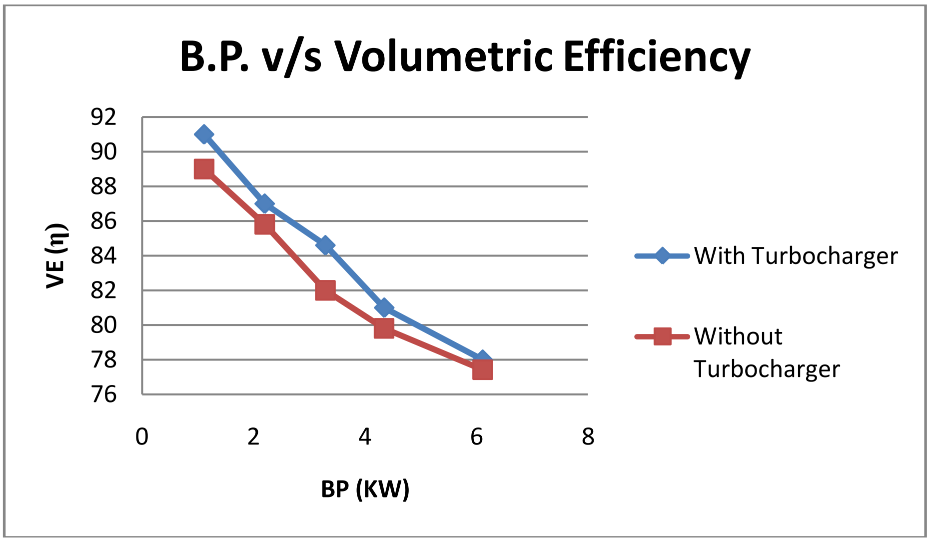

Figure 4.4: Brake Power v/s Volumetric Efficiency

Mechanical Efficiency:

It is found that the mechanical efficiency of turbocharger coupled engine is about 3 % higher than the base engine. The improvement of mechanical efficiency in turbocharger coupled engine in all load conditions were shown in the Fig. 4.5.

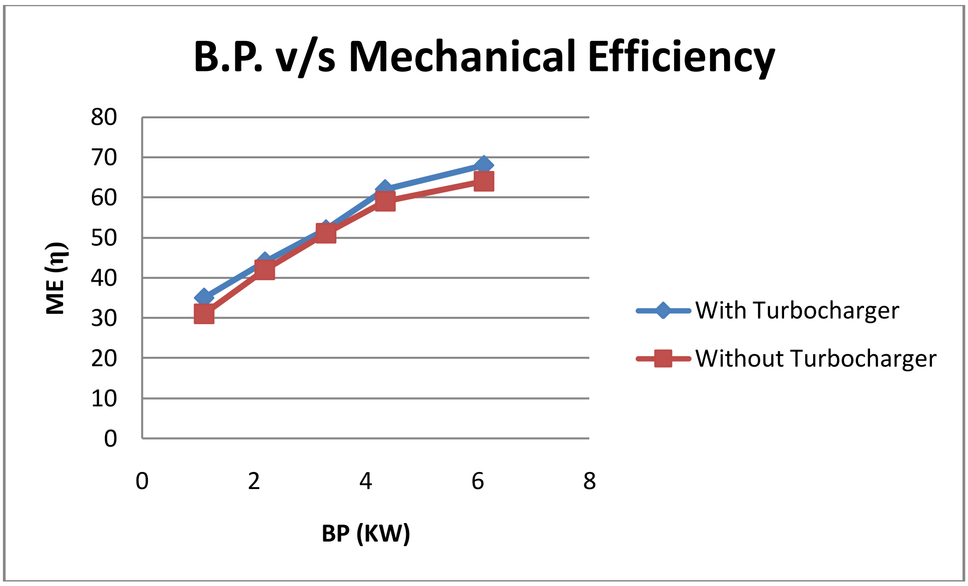

Figure 4.5: Brake Power v/s Mechanical Efficiency

Emission Test

The emission from the turbocharger coupled engine and base engine were analyzed individually. It is observed that the smoke level increase with increase in load in all load conditions. There is little decreasing in smoke level in all load conditions of turbocharged engine. At full load condition smoke density level is decrease about 2% to 6%. The smoke emissions of turbocharged engine were comparatively lesser than the Base engine. It is found that the emission increase with increase in brake power with maximum emission occurs at maximum load condition in both the case. Carbon monoxide (CO) a colourless, odourless, poisonous gas is generated in an engine which reduces in turbocharged engine when compared to the base engine. In carbon dioxides (CO_2) were exhausted from the turbocharged engine reduces compared to base engine. HC reduced almost at all load condition in case of turbocharged engine compare to base engine. Unburned hydro carbons reduced by 4% to 11% that shows better combustion due to turbocharger coupled in an engine. It is observed that the NO_X level decreased in with turbocharged engine with increase in load at all load conditions. At no load condition in case of turbocharged engine NO_X is decreased by 3%, at rated power load condition it is reduced by 14% and it is also reduce at over load condition by 7.8%. The emission characteristics were shown in the Fig. 4.6 to Fig. 4.9.

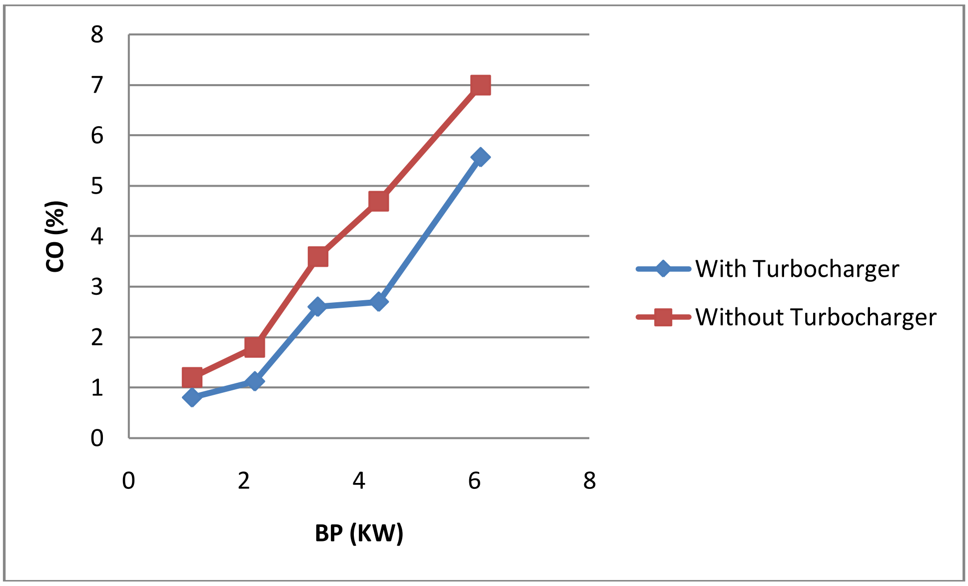

Figure 4.6: Brake Power v/s CO

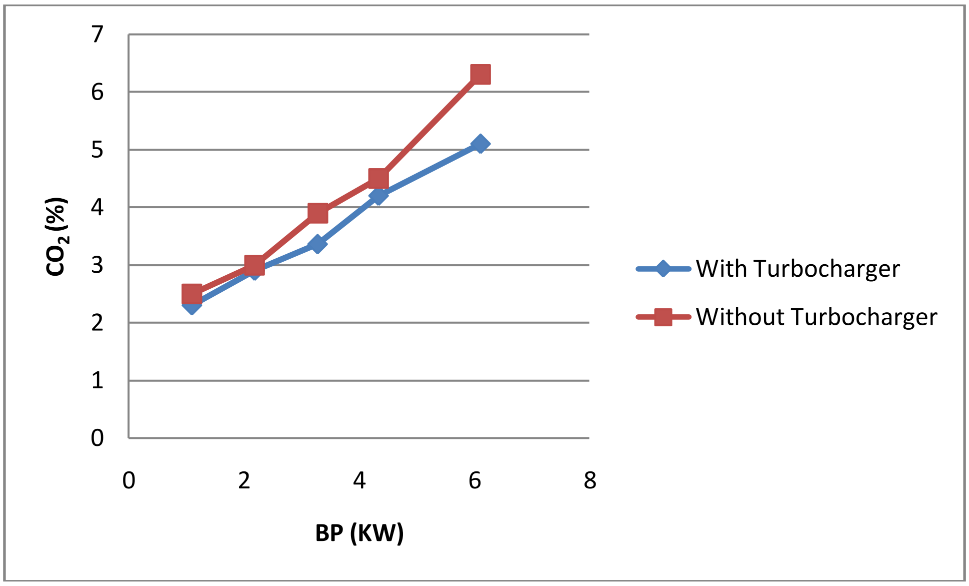

Figure 4.7: Brake Power v/s CO_2

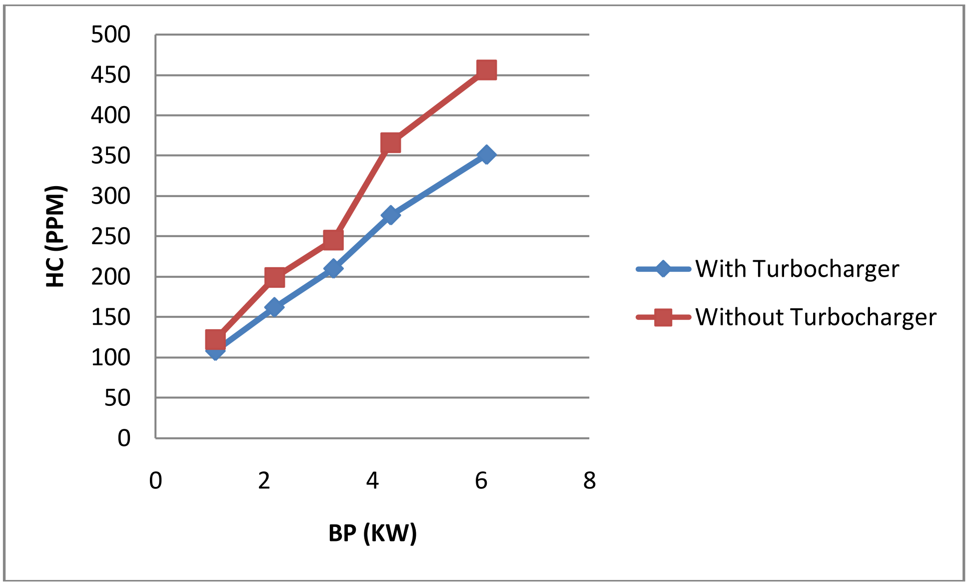

Figure 4.8: Brake Power v/s HC

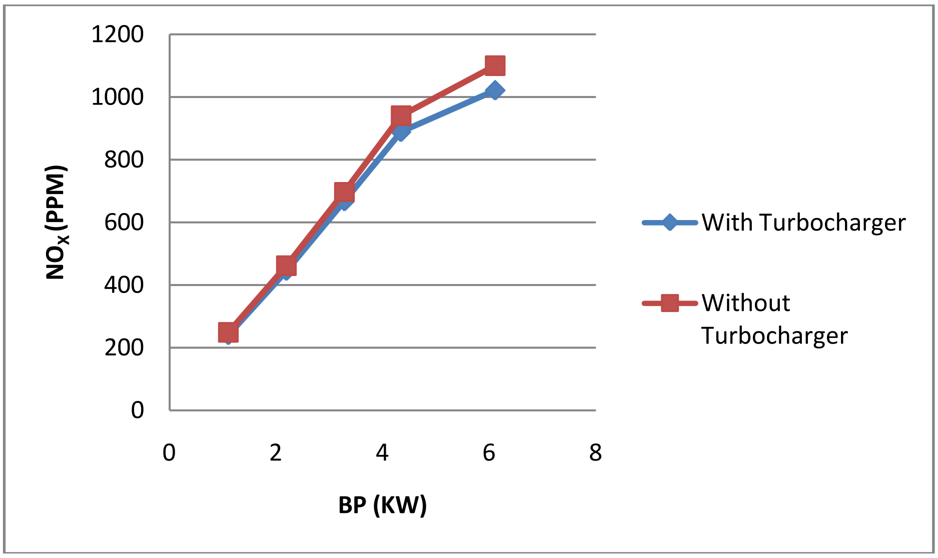

Figure 4.8: Brake Power v/s NO_X

Noise Test

Noise level limit between minimum to maximum load power condition in both engine are increased the db level. The noise level in base engine for minimum is 98 db and maximum is 110.9 db and it is for turbocharger coupled engine is 90 db and 102 db. It is found that the noise level in turbocharged engine is decreased than base engine. The variation of noise level in both case were shown in the Fig. 4.10.

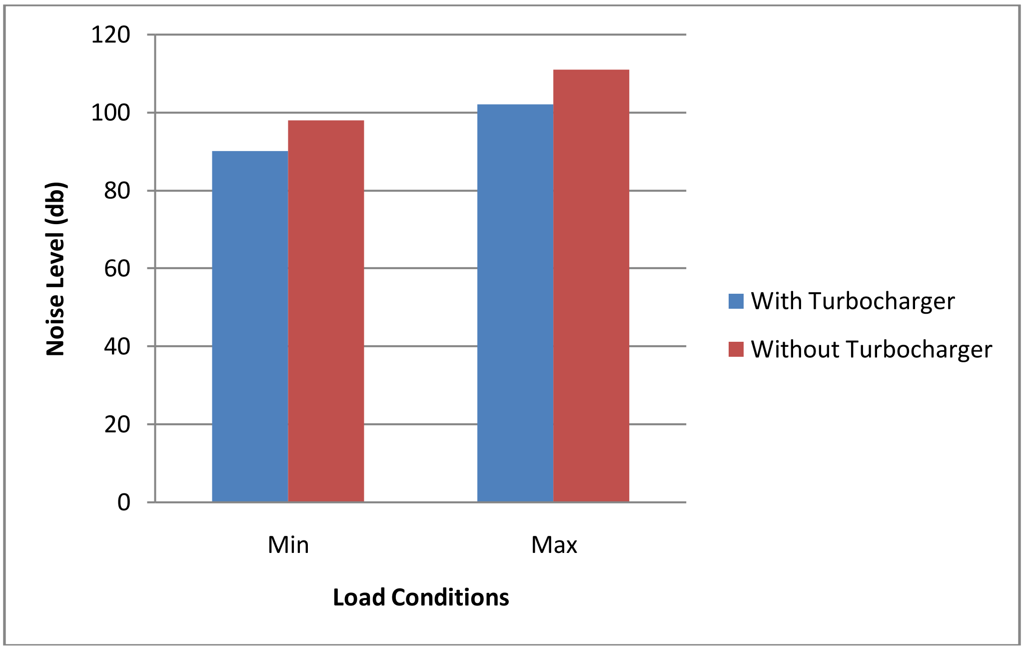

Figure 4.10: Load Conditions v/s Noise Level

Conclusion

The test is conducted on the four stroke multi cylinder diesel engine with and without turbocharger. The performance parameters and exhaust emissions were investigated experimentally in five different loads. The following were the main conclusions:

- The specific fuel consumption has little improvement in turbocharger coupled engine compared to base engine.
- The brake mean effective pressure is also nearly same at all load condition in coupled turbocharger engine when compared to base engine.
- Brake thermal efficiency is increased in turbocharger coupled engine compared to the ordinary engine in all load conditions.
- It is seen that there is slight improvement in volumetric efficiency in turbocharger coupled engine.
- It is found that the mechanical efficiency of turbocharger coupled engine is about 3 % higher than the base engine.
- Smoke density level is decreased about 2% to 6% in turbocharged engine, the amount of CO and CO2 is decreased in turbocharged engine, HC reduced almost at all load condition in turbocharged engine, Unburned hydro carbons reduced by 4% to 11% that shows better combustion due to turbocharger coupled in an engine.
- It is observed that the NO_X level decreased in with turbocharged engine about 3%, at rated power load condition it is reduced by 14% and it is also reduce at over load condition by 7.8%.
- It is found that the noise level in turbocharged engine is decreased than base engine.

References

[1] A. Pannirselvam, M. Ramajayam, V. Gurumani, S. Arulselvan, G. Karthikeyan, “Experimental studies on the performance and emission characteristics of an ethanol fumigated diesel engine”, International Journal of Engineering Research and Applications (IJERA), Vol. 2, Issue 2, Mar-Apr 2012, pp.1519-1527

[2] Qiqing Jiang, Pradheepram Ottikkutti, Jon VanGerpen and Delmar VanMeter, “The effect of Alcohol Fumigation on Diesel Flame Temperature and Emissions”, SAE 900386.

[3] A. R. Schroeder, L. D. Savage, R. A. White and S. C. Sorenson, “The Effect of Diesel Injection Timing on a Turbocharged diesel Engine Fumigated with Ethanol”, SAE 880496.

[4] Prof. A. R. Patil, Prof. Dr. S. G. Taji, Mr. Akshay N. Relekar, Mr. Anirudha N. Patil, Mr. Dhananjay Khamkar, Mr. Rohan Akhade, “Investigation on Effect of Oxygenated Additive on Multicylinder Diesel Engine Performance and Emission”, International Journal of Innovative

Research in Science, Engineering and Technology, Vol. 3, Issue 6, June 2014.

[5] P.N. Shrirao, A. N. Power, " Evaluation of performance and emission characteristics of turbocharged diesel engine with mullite as thermal barrier coating", International Journal of Engineering and technology, 3, 2011, Vol. 3,pp256-265..

[6] Murthy P.V.K., "Performance Evaluation of Low heat rejection diesel engine with pure diesel", International Journal of applied Engineering research, dindigul, 2010, Vol. 1, pp 428-451.

[7] G Lakshmi Narayana Rao, S Sampath, K Rajagopal, "Experimental Studies on the Combustion and Emission Characteristics of a Diesel EngineFuelled with Used Cooking Oil Methyl Ester and its Diesel Blends", International Journal of Applied Science, Engineering and Technology vol no 4;1 2008.

[8] Park HS, Youn IM, Lee CS. "Influence of ethanol blends on the combustion performance and exhaust emission characteristics of a four-cylinder diesel engine at various engine loads and injection timings". Fuel 2011;90:748–755.

[9] D. C. Gosai, H. J. Nagarsheth, "Evaluation of Engine Performance and Exhaust Emission Characteristics of Copper Coated Diesel Engine", International Journal of Recent Technology and Engineering (IJRTE)ISSN: 2277-3878, Volume-4 Issue-1, March 2015.

[10] Senthilkumar ,K. Ramadoss ,R. Manimaran M. Prabu, "Emission, Combustion, Performance And Characteristics Of A CI Engine Using MTBE Blended", IEEE-International Conference On Advances In Engineering, Science And Management (lCAESM -2012), 30, 31, March 2012,

[11] C.D. Rakopoulos, A.M. Dimaratos, E.G. Giakoumis, D.C. Rakopoulos, "Study of turbocharged diesel engine operation, pollutant emissions and combustion noise radiation during starting with bio-diesel or n-butanol diesel fuel blends", Applied Energy 88 (2011) 3905–3916.

[12] R Ganapathi, "Performance evaluation of ceramic coated with air insulated four stroke diesel engine", International Journal of current Engineering and technology, No.5, December 2013, Vol. 3, pp 1858-1862.