Experimental Investigations on the Performance Parameters of 4-Stroke Multi Cylinder Diesel Engine by Using Diesel and Biodiesel with Turbocharger

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Abstract: **The main aim of the engine designer, to achieve the twin goals of improved power output. There are two factors in the expression apart from number of cylinder and cubic capacity of the engine can increase the power output. The most important preferred method of increasing the power output is by means of increasing the mean effective pressure. This can be achieved by supplying air or air-fuel mixture at a pressure which is higher than the atmospheric pressure. This in turn will increase the power output of the engine. The turbocharger turbine, which consists of a turbine wheel and turbine housing, converts the engine exhaust gas into mechanical energy to drive the compressor. The gas, which is restricted by the turbine's flow cross-sectional area, results in a pressure and temperature drop between the inlet and outlet. This pressure drop is converted by the turbine into kinetic energy to drive the turbine wheel. In the present work, the natural aspiration and turbocharger provisions were made for experimental investigation. To calculate the efficiencies of the 4-stroke multi cylinder diesel engine with turbocharger by using load test, by increasing the load gradually (2kg, 4kg, 6kg, 8kg & 10kg) with the help of rope and brake drum loading system. Experimental tests provided a basis to design a control strategy able to meet general performance requirements. Finally from the experimental results shows that the performance of turbocharger is better than the natural aspiration and diesel is better than the biodiesel. The results of turbocharging gives good performance characteristics.**

***Keywords*: turbocharger, natural aspiration, diesel, bio- diesel, four stroke multi cylinder diesel engine**

I. INTRODUCTION

The turbocharger was invented by Swiss engineer Alfred Buchi. His patent for a turbocharger was applied for use in 1905. Diesel ships and locomotives with turbochargers began appearing in the 1920s.

To obtain more horse power from the engine it is necessary to burn more fuel inside the engine cylinders. For complete burning of this fuel and to give maximum heat energy, presence of more amount of air is required. But by the action of piston inside the cylinder during suction stroke always a constant volume of air only can be sucked which depends on cylinder sizes. To put in more amount of air into, the atmosphere air is pre-pressurized outside the cylinders by the use of a rotor driven blow (rotary compressor).

This machine consisting of a turbine rotor unit comprises of a turbine rotor with blades and a blower (rotary compressor) which are connected with a rotor shaft.

The turbocharger may also be used to increase fuel efficiency without any attempt to increase power. It does this by recovering waste energy in the exhaust and feeding it back into the engine intake. By using this otherwise waste energy to increase the mass of air it becomes easier to ensure that all fuel is burnt before being vented at the start of the exhaust stage. The increased temperature from the higher pressure gives a higher Carnot efficiency.

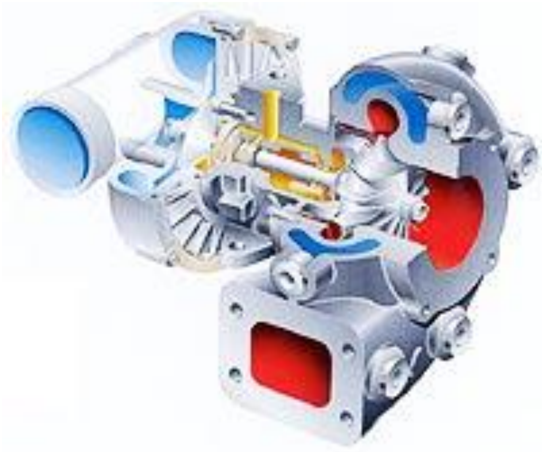


Fig.1 turbo charger

During the 1930's turbochargers were largely the preserve of marine engines, aircraft and race vehicles but gradually found their way into commercial diesel engines by the 1950's. It has been common for truck engines to be turbocharged for decades but car engines originally had difficulty in effectively employing this technology.

Very likely, the future of the internal combustion engine can be described within the energy sociopolitical environment as follows: for the foreseeable future, crude oil will still be the main energy source for internal combustion engines in automotive and other mobile applications; natural gas and, to a limited extent synthetic fuels (methanol and similar fuels), as well as, in the very long run, hydrogen, will additionally gain in importance. Internal combustion engines for these fuels are reciprocating or rotational piston combustion engines and gas and steam turbines. These engines are employed, under consideration of the particular requirements and according to their development status, in aircraft, locomotives, ships, stationary power plants, and in road vehicles.

II. AIM AND SCOPE OF PRESENT WORK

In the present work, the natural aspiration and turbocharger provisions were made for experimental evaluation. Calculated the efficiencies of the 4-stroke multi cylinder diesel engine with turbocharger by using load test. By increasing the load gradually (2kg, 4kg, 6kg, 8kg & 10kg) with the help of rope and brake drum loading system. Experimental tests provided a basis to design a control strategy able to meet general performance requirements.

Finally, the new control strategy was validated on the engine switch good results. The turbocharging is better than the natural aspiration and diesel is better than the biodiesel. The results gives a good performance characteristics.

III. NATURAL ASPIRATION

A naturally aspirated engine uses the natural atmospheric pressure and the vacuum created by the piston movement to pull in air. When the pistons fire and draw down into the engine, they pull air after them. The air then mixes with the fuel vapour and burns, creating internal combustion. This is the most common type of engine aspiration.

Description:

In a naturally aspirated engine, air for combustion (diesel cycle in a diesel engine, or specific types of otto cycle in gasoline engines – namely gasoline direct injection), or an air/fuel mixture (traditional otto cycle petrol engines) is drawn into the engines cylinders by atmospheric pressure acting against a partial vacuum that occurs as the piston travels downwards toward bottom dead centre during the induction stroke. Owing to innate restriction in the engine's inlet tract which includes the intake manifold, a small pressure drop occurs as air is drawn in, resulting in a volumetric efficiency of less than 100 percent – and a less than complete air charge in the cylinder. The density of the air charge, and therefore the engine's maximum theoretical power output, in addition to being influenced by induction system restriction, is also affected by engine speed and atmospheric pressure, the latter which decreases as the operating altitude increases.

This is in contrast to a forced induction engine, in which a mechanically driven supercharger, or an exhaust-driven turbocharger is employed to facilitate in increasing the mass of intake air beyond what could be produced by atmospheric pressure alone.

As a two-stroke diesel engine is incapable of natural aspiration as defined above, some method of charging the cylinders with scavenging air must be integrated into the engine design. This is usually achieved with a positive displacement blower driven by the crankshaft. The blower does not act as a supercharger in this application, as it is sized to produce a volume of air flow that is in direct proportion to engine's requirement for combustion, at a given power and speed. By the society of automotive engineer's definition, a mechanically scavenged two-stroke diesel engine is considered to be naturally aspirated.

Applications:

1. Most automobile petrol engines, as well as many small engines used for non-automotive purposes, are naturally aspirated.
2. Most modern diesel engines powering highway vehicles are turbocharged to produce a more favorable power-to-weight ratio, as well as better fuel efficiency and lower exhaust emissions.
3. Turbocharging is nearly universal on diesel engines that are used in railroad, marine engines, and commercial stationary applications (electrical power generation, for example).
4. Forced induction is also used with reciprocating aircraft engines to negate some of the power loss that occurs as the aircraft climbs to higher altitudes.

IV. TURBOCHARGERS

The turbocharger turbine, which consists of a turbine wheel and turbine housing, converts the engine exhaust gas into mechanical energy to drive the compressor. The gas, which is restricted by the turbine's flow cross-sectional area, results in a pressure and temperature drop between the inlet and outlet. This pressure drop is converted by the turbine into kinetic energy to drive the turbine wheel.

Components:

The turbocharger has four main components. The **turbine** (almost always a radial turbine) and impeller compressor wheels are each contained within their own folded conical housing on opposite sides of the third component, the center housing/hub rotating assembly (chra).

The housings fitted around the **compressor impeller** and **turbine** collect and direct the gas flow through the wheels as they spin. The size and shape can dictate some performance characteristics of the overall turbocharger. Often the same basic turbocharger assembly will be available from the manufacturer with multiple housing choices for the turbine and sometimes the compressor cover as well. This allows the designer of the engine system to tailor the compromises between performance, response, and efficiency to application or preference. Twin-scroll designs have two valve-operated exhaust gas inlets, a smaller sharper angled one for quick response and a larger less angled one for peak performance.

The **turbine and impeller wheel** sizes also dictate the amount of air or exhaust that can be flowed through the system, and the relative efficiency at which they operate. Generally, the larger the turbine wheel and compressor wheel, the larger the flow capacity. Measurements and shapes can vary, as well as curvature and number of blades on the wheels. Variable geometry turbochargers are further developments of these ideas.

The center hub rotating assembly (chra) houses the shaft which connects the compressor impeller and turbine. It also must contain a bearing system to suspend the shaft, allowing it to rotate at very high speed with minimal friction. For instance, in automotive applications the chra typically uses a thrust bearing or ball bearing lubricated by a constant supply of pressurized engine oil. The chra may also be considered "water cooled" by having an entry and exit point for engine coolant to be cycled. Water cooled models allow engine coolant to be used to keep the lubricating oil cooler, avoiding possible oil coking from the extreme heat found in the turbine. The development of air-foil bearings has removed this risk.

Key Components Of A Turbocharger:

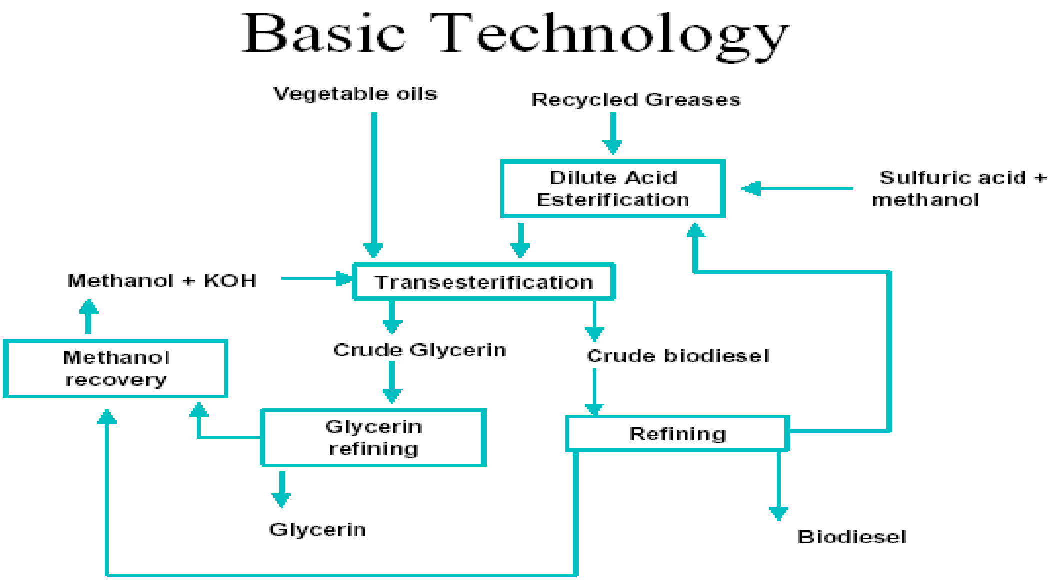
1. The turbine, which is almost always a radial inflow turbine
2. The compressor, which is almost always a centrifugal compressor
3. The center housing/hub rotating assembly
4. Many turbocharger installations use additional technologies, such as wastegates, intercooling and blow-off valves.

Biodiesel:

Biodiesel, a diesel fuel substitute that can be made from a variety of oils, fats, and greases, is of interest to farmers for a number of reasons: It can provide an additional market for vegetable oils and animal fats; it can allow farmers to grow the fuel they need for farm machinery; and it can decrease U.S. dependence on imported oil since fuel feed stocks can be grown domestically.

Biodiesel is a renewable source of energy that can help reduce greenhouse gas emissions and minimize the "carbon footprint" of agriculture. It contributes less to global warming because the carbon in the fuel was removed from the air by the plant feedstock.

In addition, biodiesel produces less air pollution (exhaust emissions) than diesel made from fossil fuels. A 1998 study by the USDA and US DOE found that using pure biodiesel in urban buses "results in substantial reductions in life cycle emissions of total particulate matter, carbon monoxide and sulfur oxides (32%, 35% and 8% reductions, respectively, relative to petroleum diesel's life cycle)."



Experimental Setup:

The Following equipment has been used for experimental work carried out in Thermal Laboratory.

1. FUEL TANK
2. BURRETTE
3. MANOMETER UNIT
4. 20.H.P FOUR STROKE MULTI CYLINDER DIESEL ENGINE
5. AIR INTAKE
6. EXHAUST GAS OUTLET
7. ENGINE EXHAUST
8. MECHANICAL LOADING UNIT
9. TURBOCHARGER UNIT

Performance Test:

A multi cylinder 4-stroke water-cooled diesel engine having 20 hp as rated power at 1500 rpm was used in the present work. The engine is coupled to an brake drum for loading it. A digital tachometer is used to measure the speed of the engine. The fuel flow rate is measured on volumetric basis using burette and a stopwatch.

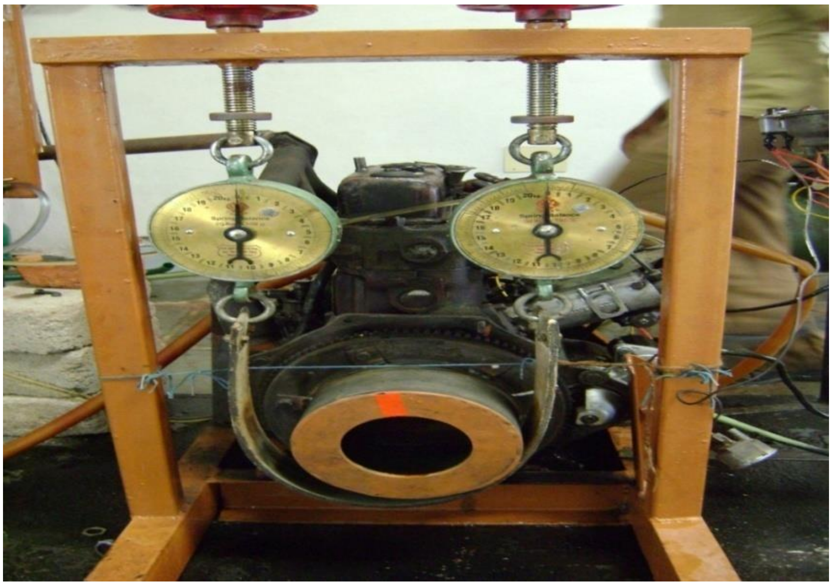


Fig.2 Experimental loading set up of 20 hp diesel engine with mechanical loading With turbocharger

Fig.3 Turbocharger set-up

Engine Specifications:

Engine	H.M Trucker
Type	Water cooled
Bore	73 mm
Stroke	90 mm
Maximum Power	20 HP
No. of cylinders	4
Injection timing	28^0 BTDC
Compression Ratio	16.5:1
Radius Of Dynamometer	207 mm
Belt thickness	7 mm

V. EXPERIMENTAL PROCEDURE

The experimental procedure is carried out through the following steps:

1. Fill the fuel tank with clean diesel fuel.
2. Connect the mechanical loading as belt and brake drum.
3. Before starting the engine preheating of air with the help of heater plugs.
4. Start the engine by cranking the crank shaft by using the self-motor with battery.
5. Load the engine mechanically by adding the weights in terms of 2, 4, 6, 8, and 10Kgs.
6. Without turbocharger take down the manometer reading for air consumption, engine RPM reading and burette reading for fuel consumption for 40cc. simultaneously emissions readings are also tabulated.
7. Instead of fuel takes place biodiesel, take down the readings same as above.
8. By attaching turbocharger unit and setup with appropriate equipments take down the manometer reading for air consumption, engine RPM reading and burette reading for fuel consumption for 40cc. simultaneously emissions readings are also tabulated.
9. Repeat the procedure with turbocharger unit by using biodiesel.
10. After completion of experiment to stop the engine by using stop lever.

Perforamance Test On Diesel Engine With Turbocharger (Model Calculations)- Using Deisel:

CALCULATIONS:

❖ **Torque:**

$$T=\frac{((w-s)\times(D+t))\times g}{2}$$

W=Load (kg)

S=spring balance reading

D=Diameter of brake drum

t=Thickness of belt

g=acceleration due to gravity

1. $T=\frac{(2-0)\times(0.207+0.007)\times 9.81}{2}$

   T=2.099 (N-m)
2. T=4.198 (N-m)
3. T=6.298 (N-m)
4. T=8.397 (N-m)
5. T=10.49 (N-m)

❖ **Brake Power:**

$$BP = \frac{2\Pi NT}{60}$$

N=speed (RPM)

T=Torque (N-m)

$$BP = \frac{2\times\Pi\times 996\times 2.099}{60}$$

1. BP = 0.218 KW

2. BP = 0.429 KW
3. BP = 0.623 KW
4. BP = 0.800 KW
5. BP = 0.955 KW

❖ **Total Fuel Consumption:**

$$\text{T.F.C} = \frac{CC}{t} \times \frac{S_f}{1000}$$

Where,

T.F.C=Total fuel consumption

CC=40 ml (amount of fuel used to take observation)

T=Time taken for 40cc fuel consumption

S_f = Specific gravity of diesel =0.85

1. T.F.C=2.70×10-4 kg/s
2. T.F.C=2.78×10-4 kg/s
3. T.F.C=2.85×10-4 kg/s
4. T.F.C=2.94×10-4 kg/s
5. T.F.C=3.06×10-4 kg/s

❖ **Frictional Power:**

FP= 0.6 kw (Using willians graph method drawn b/w BP & T.F.C)

❖ **Indicated Power:**

IP=BP+FP

1. IP= 0.818 KW
2. IP= 1.029 KW
3. IP= 1.223 KW
4. IP= 1.400 KW
5. IP= 1.555 KW

❖ **Mechanical Efficiency**

$$\eta mech = \frac{BP \times 100}{IP}$$

1. η_{mech} =26.65 %
2. η_{mech} =41.70 %
3. η_{mech} =50.90 %
4. η_{mech} =57.14 %
5. η_{mech} =61.41 %

❖ **Break Thermal Efficiency**

$$\eta_{bth} = \frac{BP \times 100}{\text{Heat input}}$$

Where,

Heat input=T.F.C×CV

1. η_{bth} = 1.92 %
2. η_{bth} = 3.67 %
3. η_{bth} = 5.20 %

4. η_{bth} = 6.90 %
5. η_{bth} = 8.76 %

❖ **Indicated Thermal Efficiency:**

$$\eta_{ith} = \frac{IP \times 100}{\text{Heat input}}$$

1. η_{ith}= 7.21 %
2. η_{ith}= 8.81 %
3. η_{ith}= 10.21 %
4. η_{ith}= 11.33 %
5. η_{ith}= 13.20 %

❖ **Volumetric Efficiency:**

$$\eta_{vol} = \frac{\text{acutal volume of flow rate of air}}{\text{The rate at which volume is displayed}}$$

$$\eta_{vol} = \frac{\text{area of orifice in air box} \times \text{velocity of air}}{\text{area of Cylinder} \times \text{length of cylinder} \times \text{revolutions per second}}$$

η_{vol}= Q_{act} / Q_{th}

Q_{act} = Actual air inlet based on orifice dia

Q_{th} = Swept volume of the piston

$Q_{act}= C_d \times A \times (2 \times g \times h_a)^{1/2}$

C_d= Co-efficient of discharge for orifice is 0.65

A = Area of orifice is $2.54 \times 10^{-4} m^2$

$h_a = h_m/1.169$

1. $Q_{act}= 7.125 \times 10^{-3}\ m^3/s$
2. $Q_{act}= 7.127 \times 10^{-3}\ m^3/s$
3. $Q_{act}= 6.996 \times 10^{-3}\ m^3/s$
4. $Q_{act}= 7.029 \times 10^{-3}\ m^3/s$
5. $Q_{act}= 7.126 \times 10^{-3}\ m^3/s$

$$Q_{th} = \frac{\Pi D^2 L n k}{4 \times 60}$$

D=Dia of piston is 0.073 m

K=No. of cylinders = 4

n=No. of power strokes (N/2)

L=Stroke length 0.09m

1. $Q_{th}=12.50 \times 10^{-3}\ m^3/s$
2. $Q_{th}=12.20 \times 10^{-3}\ m^3/s$
3. $Q_{th}=11.80 \times 10^{-3}\ m^3/s$
4. $Q_{th}=11.40 \times 10^{-3}\ m^3/s$
5. $Q_{th}=10.90 \times 10^{-3}\ m^3/s$

$\eta_{vol} = Q_{act}/Q_{th}$

1. η_{vol}= 57 %

2. η_{vol}= 58.41 %
3. η_{vol}= 59.3 %
4. η_{vol}= 61.6 %
5. η_{vol}= 65.37 %

❖ **Specific Fuel Consumption:**

S.F.C = $\frac{T.F.C}{BP}$ kg/kwhr

1. S.F.C=4.458 kg/kw hr
2. S.F.C=2.330 kg/kw hr
3. S.F.C=1.646 kg/kw hr
4. S.F.C=1.323 kg/kw hr
5. S.F.C=1.153 kg/kw hr

❖ **Air-Fuel Ratio:-**

A/F RATIO= $\frac{ma}{T.F.C}$ = $\frac{\rho a \ X \ Qact}{T.F.C}$

1. A/F RATIO =30.84
2. A/F RATIO =29.96
3. A/F RATIO =28.69
4. A/F RATIO =27.94
5. A/F RATIO =27.60

PERFORMANCE OF DIESEL ENGINE:

LOAD TEST TABLE

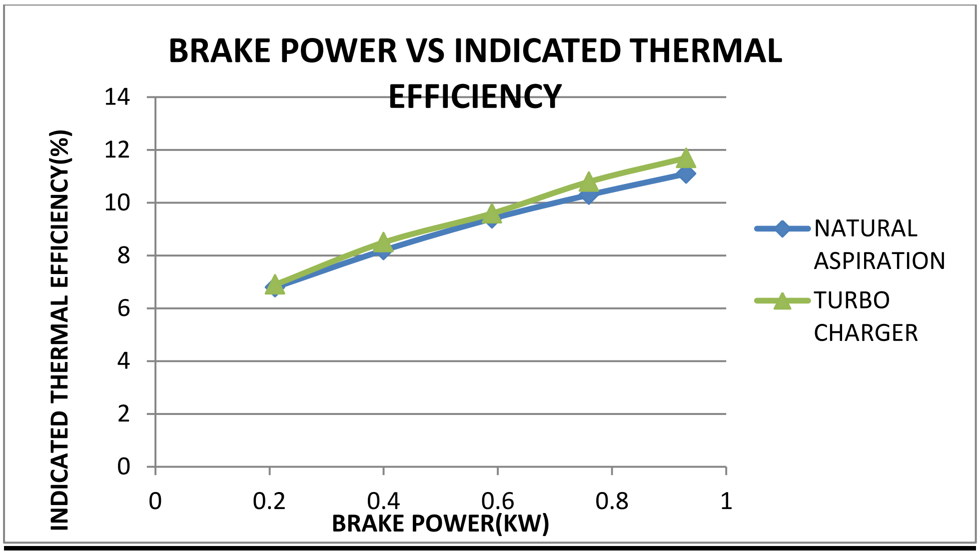
Sl. NO	Load in (Kg)	Time taken For 40cc (sec)	Speed in RPM	Air fuel ratio	Mano-meter readings		BP in KW	FP in KW	IP in KW	η_{Mec} (%)	η_{Vol} (%)	S.F.C Kg/kw hr
					H_1	H_2						
1	2	125.6	996	30.8	56	55	0.21	0.6	0.81	26.6	57	4.45
2	4	122.3	977	29.9	54	58	0.42	0.6	1.02	41.7	58.4	2.33
3	6	119.2	946	28.6	53	54	0.62	0.6	1.22	50.9	59.3	1.64
4	8	115.5	910	27.9	53	55	0.8	0.6	1.4	57.1	61.6	1.32
5	10	110.8	870	27.6	55	56	0.95	0.6	1.55	61.4	65.3	1.15

TYPE OF TEST: TURBOCHARGER, **FUEL USED:** DIESEL

VI. RESULTS & DISCUSSIONS

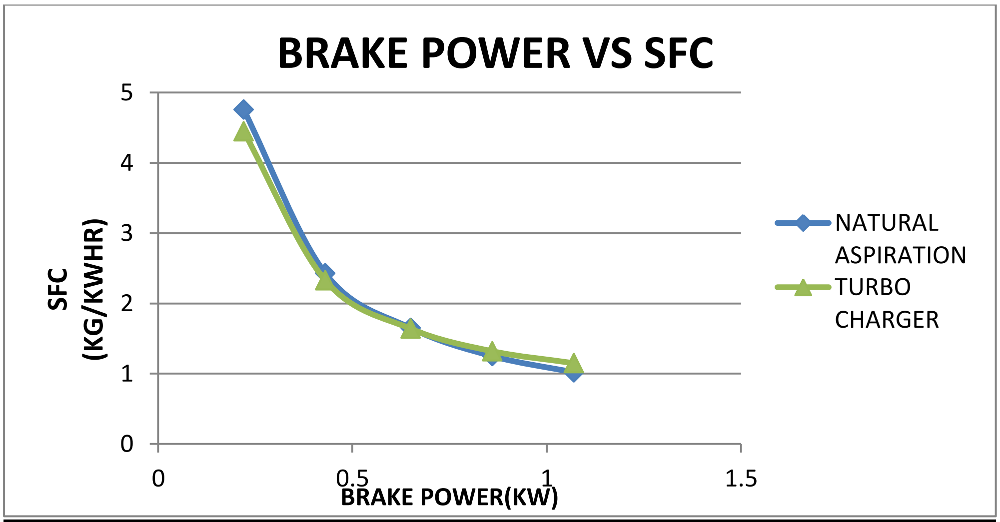
Brake Power Vs Indicated Thermal Efficiency:

Comparison of the natural aspiration and turbocharger between BRAKE POWER vs INDICATED THERMAL EFFICIENCY



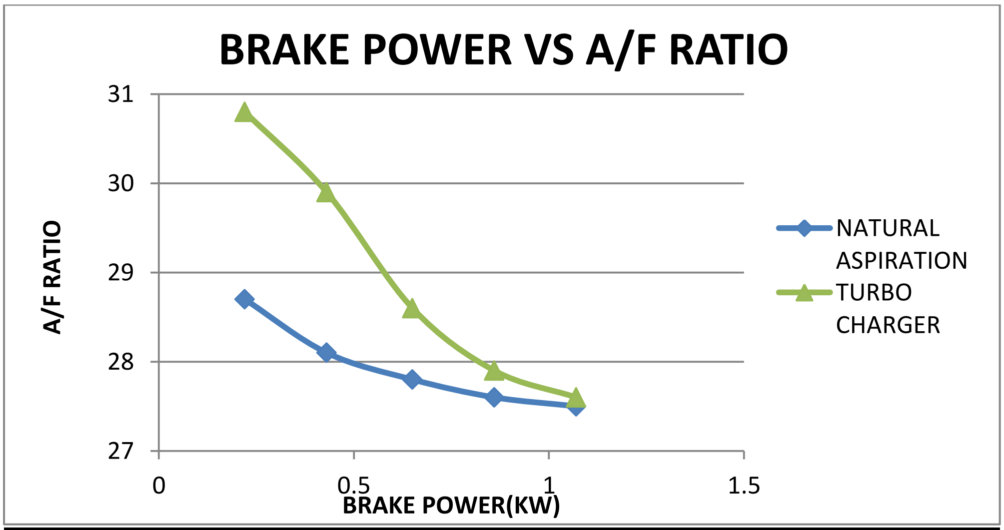
Brake Power Vs Sfc

Comparison of the natural aspiration and turbocharger between BRAKE POWER vs SFC



Brake Power Vs A/F Ratio

Comparison of the natural aspiration and turbocharger between BRAKE POWER vs A/F RATIO



VII. CONCLUSIONS

Tests were carried on a 20 H.P in-direct injection compression ignition engine fueled with diesel. The engine was modified with the turbocharger provision has been incorporated to increase the pressure and temperature of the intake air and the results obtained were analyzed in terms of performance

From the results and discussions of the experimental investigations on a 4-stroke, multi cylinder, idle speed, stationary, water cooled, compression ignition engine run on diesel, then the following conclusions are drawn

- The power of the engine can be increased by increasing the mean effective pressure this can be done by Turbocharging.
- The power of the engine can be increased by increasing the mean pressure this can be done by Turbocharging.
- Volumetric efficiency of the engine is increased by1.5% using turbocharging compared to natural aspiration.
- Mechanical efficiency of the engine is increased by 12% using turbocharger respectively compared to natural aspiration.
- Specific fuel consumption was reduced by 0.020 kg/kwhr by providing turbocharging compared to natural aspiration.
- Turbocharging is economically better than the Natural aspiration, because turbocharger can be driven by utilizing the exhaust gases.
- Air-fuel ratio is high in turbocharging compare to natural aspiration. The air-fuel ratio in turbocharging 36:1.
- Diesel knocking was reduced by providing Turbocharging by observing the engine noise.

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