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PERFORMANCE ANALYSIS OF A FOUR STROKE SINGLE CYLINDER DIESEL ENGINE BY USING TURBO CHARGER.

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Abstract: Nowadays, turbo chargers and super chargers are employed in I.C engines. It is known that power output of engine increases with the increase in amount of air fuel mixture in the cylinder. This study has been undertaken to show the enhancement of performance of an engine using turbo charger may multiply output of an i.c engine without need to increase the size of cylinder. The turbo charger plays an important role to increase the amount of air. The turbo chargers are now becoming more and more popular in automobile applications. The aim of the turbo charger is to increase the engine volumetric efficiency by increasing density of intake gas (air) allowing more power per engine cycle. The purpose of the turbo chargers is increasing power output of the engine by supplying compressed air.

Key words: Turbo charger, 4-Stroke Single Cylinder Diesel Engine, Volumetric efficiency.

1.1. Introduction:

A turbocharger is a device that increases the air pressure fed to an internal combustion engine. It consists of a turbine and a compressor, which are connected by a common shaft. Exhaust gases from the engine drive the turbine, which in turn drives the compressor to compress the incoming air. This compressed air is then mixed with fuel and burned in the engine, resulting in a higher mass of air entering the cylinders and a corresponding increase in engine power. Turbochargers are commonly used in gasoline and diesel engines, particularly in high-performance or racing applications where increased power is needed. They can also be used to improve the efficiency of diesel engines by increasing the air pressure at low engine speeds, which can help to reduce emissions.

1.2 HISTORY OF A TURBO CHARGER:

Prior to the invention of the turbocharger, forced induction was only possible using mechanically powered superchargers. Use of superchargers began in 1878, when several supercharged two-stroke gas engines were built using a design by Scottish engineer Dugald Clerk. Then in 1885, Gottlieb Daimler patented the technique of using a gear-driven pump to force air into an internal combustion engine. The 1905 patent by Alfred Büchi, a Swiss engineer working at Sulzer is often considered the birth of the turbocharger. This patent was for a compound radial engine with an exhaust-driven axial flow turbine and compressor mounted on a common shaft. The first prototype was finished in 1915 with the aim of overcoming the power loss experienced by aircraft engines due to the decreased density of air at high altitudes. However, the prototype was not reliable and did not reach production. Another early patent for turbochargers was applied for in 1916 by French 1steam turbine inventor Auguste Rateau, for their intended use on the Renault engines used by French fighter planes. Separately, testing in 1917 by the National Advisory Committee for Aeronautics (NACA) and Sanford Alexander Moss showed that a turbocharger could enable an engine to avoid any power loss (compared with the power produced at sea level) at an altitude of up to 4,250 m (13,944 ft) above sea level. The testing was conducted at Pikes Peak in the United States using the Liberty L-12 aircraft engine. The first commercial application of a turbocharger was in 1925, when Alfred Bucchi successfully installed turbochargers on ten-cylinder diesel engines, increasing the power output from 1,300 to 1,860 kilowatts (1,750 to 2,500 hp). This engine was used by the German Ministry of Transport for two large passenger ships called the Preussen and Hanse Stadt Danzig. The design was licensed to several manufacturers and turbochargers began to be used in marine, railcar and large stationary applications. Turbochargers were used on several aircraft engines during World War II, beginning with the Boeing B-17 Flying Fortress in 1938, which used turbochargers produced by General Electric. Other early turbocharged airplanes included the Consolidated B-24 Liberator, Lockheed P-38 Lightning, Republic P-47 Thunderbolt and experimental variants of the Focke-Wulf Fw 190 as shown in fig 1

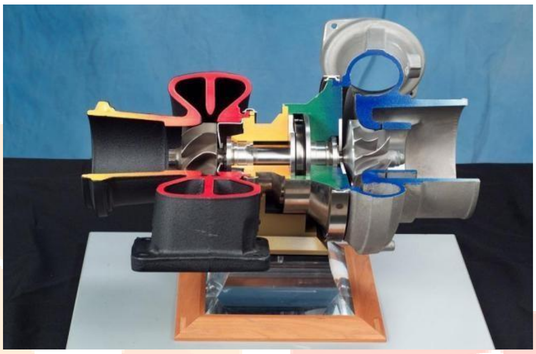

Fig1: Cut Section of Turbo Charger **1.3 Design:**

Like other forced induction devices, a compressor in the turbocharger pressurizes the intake air before it enters the inlet manifold. In the case of a 23 turbocharger, the compressor, is powered by the kinetic energy of the engine's exhaust gases, which is extracted by the turbocharger's turbine.

The main components of the turbocharger are:

- Turbine – usually a radial turbine design
- Compressor – usually a centrifugal compressor
- Center housing hub rotating assembly

1.4 CLASSIFICATION OF TURBO CHARGERS:

1. Single-Turbo.
2. Twin-Turbo.
3. Twin-Scroll Turbo.
4. Variable Geometry Turbo.
5. Variable Twin Scroll Turbo.
6. Electric turbo.

1.5 Functions of a Turbo Charger:

A turbocharger serves the following functions in an internal combustion engine:

Increasing engine power: By compressing the incoming air, a turbocharger allows more air to be drawn into the engine, which can be mixed with more fuel to create a more powerful combustion.

This results in increased engine power and torque output.

Improving engine efficiency: By compressing the air, the turbocharger increases the engine's volumetric efficiency, which can result in improved fuel efficiency and reduced emissions.

Reducing turbo lag: A turbocharger's quick response time and ability to provide a consistent boost in air pressure can help to reduce the delay or "turbo lag" that can be experienced with some conventional turbochargers.

Supporting engine performance at high altitudes: A turbocharger can help to compensate for the reduced air pressure and density at high altitudes, which can help to maintain the engine's performance.

Overall, the use of a turbocharger can help to increase the power and efficiency of an internal combustion engine, making it a popular choice in high-performance and racing applications, as well as in diesel engines.

2. LITERATURE REVIEW

Mukhtar Ahmad et. al.[1] In his work, turbochargers are used to increase an internal combustion engine's output without adding more cylinders. The use of such a mechanical mechanism enables automakers to downsize their engines, often known as engine downsizing, to smaller displacements. In order to maximize the capability of an IC engine that was already powerful, such as those utilized in motor sport, turbochargers were frequently installed. Today, the focus is on developing a workable engineering answer for manufacturing economics and "greener" road vehicles. These factors have led to a significant increase in the use of turbochargers in applications for the automotive industry. The goal of this study is to provide an overview of the most recent turbocharging systems utilized to maximize engine efficiency and exhaust emissions.

SK.Abdul Azeez et. al. [2]He explained the many kinds of superchargers and turbochargers in contemporary trends and to determine how useful they are now. As the demand for more modern, environmentally friendly engines grows, new technologies are being created. By turbo-charging the engine, greater power can be achieved with low emissions because combustion emissions will increase as a result of the rich air fuel mixture.By examining its effects, the behaviour of an internal combustion engine with a turbocharger or supercharger installed is investigated. As you ascend, the density of the surrounding atmosphere decreases. However, because of the shifting overall system efficiency and pumping process, boost pressure recovery cannot guarantee the power recovery of diesel engines.

M .Herzwan, **et. al. [3]** He explained the increasing consumer demand for fuel-efficient vehicles and stricter emission restrictions, engine downsizing has been common in modern automobiles in recent years. Along with this pattern, turbocharging is also becoming increasingly popular as a way to boost the power of small engines. such that it can deliver an output comparable to an engine with a larger displacement. This study reviews recent research on turbochargers in three main areas: heat transfer, flow, and mechanical studies. Studies on heat transfer show the results of heat transfer modelling and experimentation. Reviews for flow studies are divided according to the many turbocharger components and research methodologies.

Fatima M Elaf et. al. [4]She explained one of the most significant heat engines in several power fields is the medium-speed diesel engine.facilities like those that produce electric power and marine prime movers. This article models and simulates a medium-speed M.A.N production engine firm that has an inter-cooler and a turbocharger. The influence of the air temperature entering the engine cylinder through the inter-cooler on the volumetric efficiency is theoretically investigated using the fortran language, which is based on applied thermodynamics for internal combustion engines. The findings demonstrate that the engine performance is significantly impacted by the air temperature from the inter cooler to the engine cylinder. Results show that while the inter-cooler is working with low exit air temperature, volumetric efficiency has enhanced by around 98%.

K.M. Arun raja et. al. [5] In his work on engine power while turbo charger works on exhaust gases. Turbochargers are used throughout the automotive industry as they can enhance the output of an internal combustion (IC) engine without the need to increase its cylinder capacity. Small modification is done on vehicle to improve efficiency and also control the exhaust gas emission level. The aim of this project is to increase to volumetric efficiency and also control the emission level of two wheeler.

Daryoush Mirza-Hekmati et. al. [6] He works on the Diesel engines continue to be used in truck applications, so reducing fuel use and hence CO2 emissions, is a priority . Single-stage turbocharged diesel engines are known to be fuel efficient under steady load at low speeds. This paper develops a two-stage, in series, air-path configuration, which improves the typical part-load performance at low engine-speeds through adjustments to the turbine expansion ratios. Better EGR rates (for NOx reduction) at low engine speeds can be achieved whilst the engine transient response is maintained.

P. S. Ranjit et. al. [7] He explained the comparison of the performance and emission results obtained by running the IDI CI engine with and without the turbocharger on diesel fuel. A turbocharger can significantly improve an engine horsepower without significantly increasing its weight.The engine was run at constant rated speed (1000 rpm) and various performance, combustion and emission characteristics were measured at different engine load (25% to 100%) using a loading panel to apply load. A proper test setup was prepared by connecting the engine with Smoke Meter and 5 Gas Analyzer. The performance and emission data of the engine was noted at different loads. The performance characteristics (i.e., brake specific fuel consumption and thermal efficiency) were

calculated using mathematical relations.

11**Hualei Li**, **et. al. [8]**He proposed the recovering the boost pressure is very important in improving the dynamic performance of diesel engines at high altitudes. A regulated two-stage turbocharging system is an adequate solution for power recovery of diesel engines. In the present study, the change of boost pressure and engine power at different altitudes was investigated, and a regulated two-stage turbocharging system was constructed with an original turbocharger and a matched low pressure turbochargers. The boost pressure recovery could not ensure power recovery over the entire operating range of the diesel engine, because of variation in overall turbocharger efficiency. The fuelinjection compensation method along with the valve control strategies for boost pressure recovery was able to reach the power recovery target.

Lucian Chiriac et. al. [9]He explained the process of internal combustion engines shows that their efficiency can be increased through several technical and functional solutions. One of these is turbocharging. For certain engine operating modes, the available energy of the turbine can also be used to drive an electricity generator. The purpose of this paper is to highlight the possibilities and limitations of this solution. For this purpose, several investigations were carried out in the virtual environment with the AME Sim program, as well as experimental research on a diesel engine for automobiles and on a stand for testing turbochargers (Turbo Test Pro produced by CIMAT). The article also includes a comparative study between the power and torque of the naturally aspirated internal combustion engine and equipped with a hybrid turbocharger. The results showed that the turbocharger has a very high operating potential and can be coupled with a generator without decreasing the efficiency of the turbocharger or the internal combustion engine. The main result was the generation of electrical power of 115 W at a turbocharger shaft speed of 140,000–160,000 rpm with an electric generator shaft speed of 14,000–16,000 rpm. There are many constructive solutions for electrical turbochargers with the generator positioned between the compressor and the turbine wheel. This paper is presenting a solution of a hybrid turbocharger with the generator positioned and coupled with the compressor wheel on the exterior side.

Mukesh Saxena et. al. [10] He explained the comparison of the performance and emission results obtained by running the IDI CI engine with and without the turbocharger on diesel fuel. A turbocharger can significantly improve an engine horsepower without significantly increasing its weight. The engine was run at constant rated speed (1000 rpm) and various performance, combustion and emission characteristics were measured at different engine load (25% to 100%) using a loading panel to apply load. A proper test setup was prepared by connecting the engine with Smoke Meter and 5 Gas-Analyzer. The performance characteristics (i.e., brake specific fuel consumption and thermal were calculated using mathematical relations.

3.Fabrication Set up

3.1 WORKING OF FOUR STROKE CYCLE DIESEL ENGINE:

The working cycle of the engine is completed in four- strokes and diesel is used as fuel, therefore, it is known as four stroke diesel engines. The working of the engine is described as follows as shown in fig 3

1. **Suction stroke**: During the suction stroke of a Diesel engine only air is taken into the cylinder while the piston moves from top dead centre to bottom dead centre as shown in fig 2.1

2. **Compression stroke:** During the compression stroke the air is compressed and near the end of compression, pressure and temperature of the air is about 60 bars and 600^0 c respectively. The fuel is injected into the cylinder with the help of an injector into this compressed air which initiates combustion as shown in fig 2.2

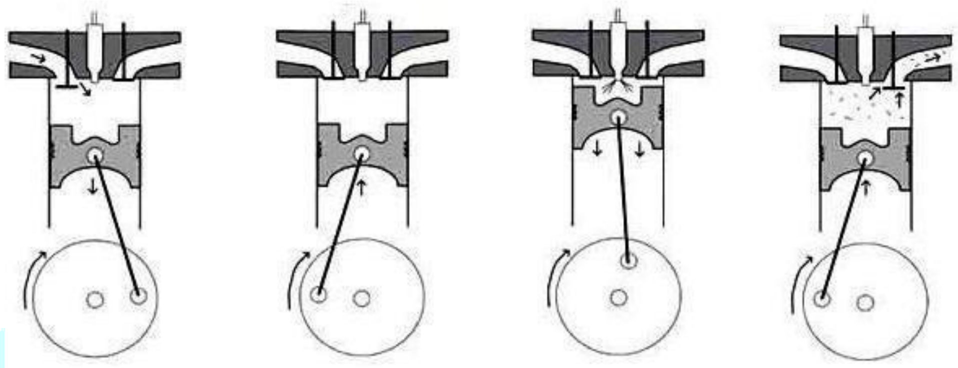

Fig :2.1 Induction **Fig:2.2** Compression **Fig:2.3** Expansion **Fig:2.4** Exhaust

Fig :2 Working of a Four Stroke Single Cylinder Engine

3. **Expansion stroke:** During this stroke, the inlet and exhaust valves are closed and the high pressure gases resulting from combustion, pushes the piston in downward direction which is called as Expansion/power stroke. The supply of fuel is continued during a small part of the expansion stroke. The temperature of the air at the end of compression stroke is sufficient to ignite the fuel. The combustion of fuel is continued at constant pressure as long as the fuel injection continues as shown in fig 1.3

4. **Exhaust stroke:** During this stroke, the inlet valve remains closed and exhaust valve opens. The17 piston moves up in the cylinder and pushes out the burnt gases. The piston reaches the TDC completing the exhaust and is ready for the next cycle as shown fig 1.4

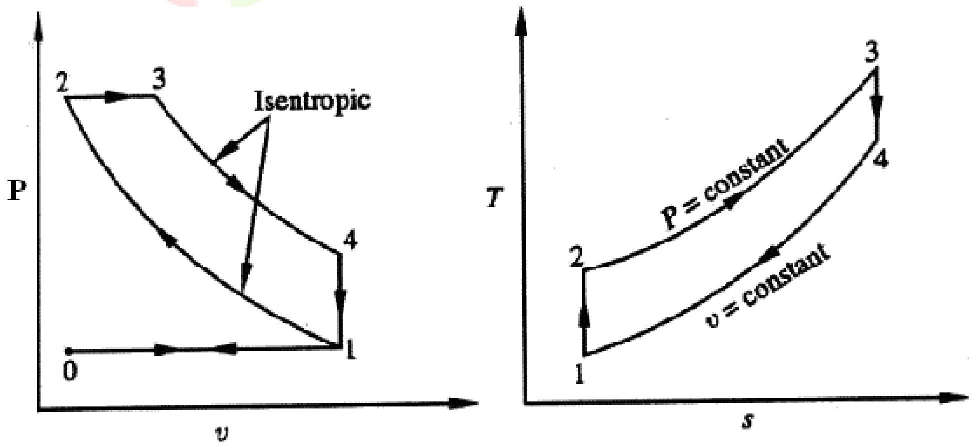

Fig :3 Representation of Diesel cycle on P-v and T-s diagrams

2.2 INSTRUMENTATION:

1. Digital RPM Indicator to measure the speed of the engine.
2. Digital temperature indicator to measure various temperatures.
3. U tube manometer to measure quantity of air sucked into cylinder.
4. Burette with stop cock to measure the rate of fuel consumed during test.

Table:1 SPECIFICATIONS OF A SINGLE CYLINDER DIESEL ENGINE:

ENGINE	FOUR STROKE SINGLE CYLINDER
MAKE	KIRLOSKAR
BHP	5 HP
RPM	1500
FUEL	DIESEL
BORE	80 mm
STROKE LENGTH	110 mm
STARTING	CRANKING
WORKING CYCLE	FOUR STROKE
METHOD OF COOLING	WATER COOLED
METHOD OF IGNITION	COMPRESSION IGNITION

LOADING SYSTEM:

The brake drum is directly coupled to the engine flywheel. It consists of several turns of rope wound around the rotating drum attached to the output shaft. The rope is connected to spring balances on either side. The power is absorbed in friction between the rope and the drum. The drum, therefore, requires cooling.

FUEL MEASUREMENT:

The fuel is supplied to the engine from the main fuel tank through a graduated measuring fuel gauge (Burette). To measure the fuel, close the stop cock and start the stop clock, measure the time taken for the consumption of X cc of fuel.

AIR INTAKE MEASUREMENT:

The suction side of the engine is connected to an Air box. The atmospheric air is drawn into the engine cylinder through the air box. The manometer is provided to measure the pressure drop across an orifice provided in the intake pipe of the Air box. This pressure drop is used to calculate the volume of air drawn into the cylinder. (Orifice diameter is 20 mm).

Fig : 4 Single Cylinder Four Stroke Diesel Engine Test Rig (without Turbo charger)

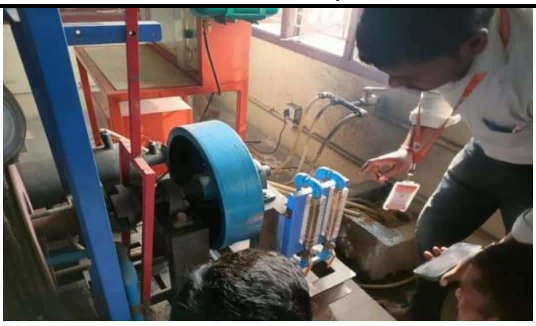

Fig : 5 Manometer readings (Without Turbo charger)

Fig :6 Single Cylinder Diesel Engine

Fig :7 Turbo Charger for 4-Stroke Single Cylinder Diesel Engine

Fig :8 Single Cylinder Diesel Engine with Turbo Charger

Fig :9 Experimentation with Turbo Charger

3.3 Fabrication set up for fixing turbo charger

An experimental setup for fixing a turbocharger to an internal combustion engine typically involves

the following steps:

Engine selection: Choose an internal combustion engine that is compatible with the turbocharger to be used in the experiment as shown in fig 6

Turbocharger selection: Select a turbocharger that is suitable for the engine selected in step 1. This may include considering the turbocharger's size, wastegate size, and maximum boost pressurePreparation of engine and turbocharger: Clean and inspect both the engine and turbocharger to ensure that they are in good working condition as shown in fig 7

Mounting the turbocharger: Attach the turbocharger to the engine using flanges and bolts. Make sure, that the turbocharger is mounted in the correct orientation, with the exhaust inlet facing the engine's exhaust manifold and the air inlet facing the air intake as fig 8

Connecting the oil supply and drain lines: Connect the oil supply line from the engine to the turbocharger to provide lubrication. Connect the oil drain line from the turbocharger to the engine to return the used oil.

Connecting the coolant lines: Connect the coolant lines from the engine to the turbocharger to provide cooling.

Connecting the wastegate: Attach the wastegate to the turbocharger's exhaust housing. The wastegate controls the amount of exhaust that flows through the turbocharger and helps to regulate the boost pressure.

Testing the setup: Start the engine and perform a series of tests to ensure that the turbocharger is functioning properly. This may include monitoring the boost pressure, exhaust gas temperature, and oil pressure.

5. Methodology

Table 2: Observation table for 4-Stroke Single Cylinder Diesel engine without Turbo Charger

Sl. No.	Load (S1-S2) Kg	Speed (N) Rpm	Time for 10cc fuel consumption.	manometer reading(h) =(h1-h2)	Fuel Consumption kg/hr	Specific Fuel Consumption kg/kW	B.P kW
1.	0-0	1530	0	8.76	24.8	34.5	0
2.	4-0.2	1514	1.03	10.61	25.8	40.4	14.8
3.	8-0.8	1500	1.94	9.60	25.3	39.3	20.6
4.	12-1.2	1488	2.91	9.88	26.6	37.8	20.7
5.	16-2.6	1472	3.5	10.87	24.5	44.8	26

4.1 CALCULATION

1.Load at 0 kg

1. **Brake power(BP)**=2πN(S1−S2) (D+d/2) *9.81/ 60000

   =2πN (0−0) (0.33+0.02/2) *9.81/ 60000

   BP=0KW

2. **Mass of fuel consumption(mfc)** = (X∗ S∗ 3600)/ (t∗ 1000)

   = (10∗ 0,82∗ 3600)/ (57∗ 1000)

   =0.5178kg/hr

3. .**Actual volume (Va)**= Cd∗ a√2gH∗ 3600

   = (H = h ∗ ρ w /1000∗ ρa *12.57)

   =0.62∗ 0.0254∗ √ (2∗ 9.81∗ 12.57) ∗ 3600

   (Va) =8.7m^3/hr

4.**Swept volume (Vs)**=π/4∗ D^2∗ L∗ N/2∗ 60

=π/4∗ 0.08^2∗ 0.11∗ 1530/2∗ 60

=25.11m^3/hr

5.**Volumetric efficiency(ηvol)**=Va/Vs∗ 100

=8.76/25.37∗ 100

=34.55%

6.**Brake thermal efficiency** = BP∗ 3600/mfc∗ cv

=0∗ 3600/0.5178∗ 42500

=0%

7.**Indicated power (Ip)**=BP+FP

= 0+2.7

=2.7KW

8.**Mechanical efficiency(ηmech)**= BP/IP

=0/2.7

ηmec*h*=0%

2. **Load at 4kg**

1.	Brake power (BP)	=1.034kw
2.	Mass off fuel consumption (MFC)	=0.5904kg/hr
3.	Actual volume (VA)	=10.61m^3/*hr*
4.	Swept volume (VS)	=25.37m^3/*hr*
5.	Volumetric efficiency (ηvol)	=40.46%
6.	Brake thermal efficiency(ηbt*h*)	=18.83%
7.	Indicated power (Ip)	=3.734kw
8.	Mechanical efficiency(ηmec*h*)	=27.72%

3. Load at 8kg

1. Brake power (BP) =1.9415kw
2. Mass off fuel consumption (MFC) =0.7978kg/hr
3. Actual volume (VA) =9.60m^3/*h*r
4. Swept volume (VS) =24.68m^3/*h*r
5. Volumetric efficiency(ηvol) =39.37%
6. Brake thermal efficiency(ηbt*h*) =20.61%
7. Indicated power(ip) =4.64915kw
8. Mechanical efficiency(ηmec*h*) =41.56%

4.Load at 12kg

1. Brake power (BP) =2.91kw
2. Mass off fuel consumption (MFC) =0.9225kg/hr
3. Actual volume (VA) =9.33m^3/hr.
4. Swept volume (Vs) =24.41m^3/hr.
5. Volumetric efficiency(ηvol) =37.80%
6. Brake thermal efficiency(ηbt*h*) =26.74%
7. Indicated power(ip) =5.61kw
8. Mechanical efficiency(ηmec*h*) =51.92%

5.Load at 16kg

1. Brake power (BP) =3.5kw
2. Mass off fuel consumption(mfc) =01.1358kg/hr
3. Actual volume (VA) =10.87m^3/hr.
4. Swept volume (Vs) =24.88m^3/hr.
5. Volumetric efficiency(ηvol) =44.53%
6. Brake thermal efficiency(ηbt*h*) =96.11%
7. Indicated power (Ip) =6.2kw
8. Mechanical efficiency(ηmec*h*) =56.45%

Table 2: Caluculation table for 4-Stroke Single Cylinder Diessel engine without Turbo Charger

Sl. No.	Load (S1-S2) Kg	Speed (N) Rpm	B.P (kw)	VA (m^3/hr)	Vs (m^3/hr)	ηvol (%)	ηbth (%)	F.P(K.W)	ηmec %	IP(KW) (%)	Time taken for fuel consumption fo 10 cc fuel
1.	0-0	1530	0	8.76	24.8	34.5	0	2.7	0	2.7	57
2.	4-0.2	1514	1.03	10.61	25.8	40.4	14.8	2.7	27.7	3.7	50.
3.	8-0.8	1500	1.94	9.60	25.3	39.3	20.6	2.7	41.5	4.6	37
4.	12-1.2	1488	2.91	9.88	26.6	37.8	20.7	2.7	51.9	5.6	32
5.	16-2.6	1472	3.5	10.87	24.5	44.8	26	2.7	56.6	6	26

Table 3: Calculation table for 4 Stroke Single Cylinder Diesel Engine with Turbo charger

Sl. No.		Load (S1 - S2)	Speed (N) Rpm	B.P (kW)	Va (m^3/hr)	Vs (m^3/hr)	ηvol (%)	ηbth (%)	F.P(K.W)	ηmec %	IP(KW)	Time taken for fuel consumption for 10 cc fuel
1.		0	1530	0	8.73	24.9	38.62	0	2	0	2.7	58
2.		4	1514	1.93	10.62	25.11	45.62	17.8	2	30.2	3.7	49.
3.		8	1500	1.91	9.80	25.32	43.5	22.3	2	43.2	4.6	38
4.		12	1488	3.2	10.2	27.32	42.5	23.5	2	52.5	5.6	34
5.		16	1472	3.34	12.04	24.41	49	48.11	2	59	6	25

Table4: Comparison Table (16 kg load)

Parameters	With out Turbo Charger	With Turbo Charger
Volumetric efficiency	44.8%	49%
Brake thermal efficiency	26%	48.11%
Mechanical efficiency	56.6%	59%

4 .Results and Discussion

Increased power and performance: Turbochargers increase the amount of air that is compressed and delivered to the engine, which can result in increased horsepower and torque. This can make the engine more responsive and provide improved acceleration.

Improved fuel efficiency: By compressing more air into the engine, turbochargers can improve the engine's fuel efficiency. This can result in lower fuel consumption and reduced emissions.

Enhanced reliability: Turbochargers are designed to be durable and reliable, and they can help to extend the life of the engine by reducing its load.

Improved engine response: Turbochargers can provide near-instant boost, resulting in improved throttle response and reduced lag.

Increased versatility: Turbochargers can be used in a wide range of internal combustion engines, from small passenger cars to large commercial vehicles.

It's important to note that while fixing a turbocharger to an engine can result in these benefits, it can also introduce some challenges. For example, turbochargers can be more complex and require more maintenance than naturally aspirated engines. In addition, turbochargers can generate more heat and increase the engine's stress, which can result in increased wear and tear. Therefore, it's important to choose the right turbocharger for the engine and to maintain it properly to ensure optimal performance and reliability.

5. CONCLUSION

In conclusion, turbochargers are a popular and effective way of increasing the power and performance of internal combustion engines. They work by compressing air and delivering it to the engine, which results in increased horsepower and torque. Turbochargers can also improve fuel efficiency, enhance reliability, improve engine response, and increase versatility.

However, it's important to consider the potential challenges associated with turbochargers, including increased complexity and maintenance requirements. It's also essential to choose the right turbocharger for the engine and to maintain it properly to ensure optimal performance and reliability. Overall, turbochargers can provide significant benefits for internal combustion engines, making them a popular choice for automotive enthusiasts and vehicle manufacturers alike.

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