



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 3, March 2023

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

 9940 572 462

 6381 907 438

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 www.ijirset.com

Performance Analysis of Turbocharging System on Single Cylinder Four Stroke S.I. Engine

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ABSTRACT: The progress of automobiles for transportation has been intimately associated with the progress of civilization. The automobile of today is the result of the accumulation of many years of pioneering research and development. An attempt has been made in this project; the exhaust gas is used to rotate the turbine with blower arrangement. Exhaust gas is used to rotate the blower and this air is given to the ignition input supply. In general, Turbochargers are used throughout the automotive industry as they can enhance the output of an internal combustion engine without the need to increase its capacity. A study on the effect of turbocharger on a single cylinder two wheeler engine is made in this work. Also, the fabrication and installation of turbocharger in a single cylinder is available in this literature. We have fabricated a prototype model of turbocharger and implemented on a four-stroke petrol engine by which, the fuel efficiency and mileage of the engine can be increased. Thus, our aim in selecting this paper is to highlight the effectiveness of turbocharging.

KEYWORDS: Turbocharger, S.I. Engine, Fuel Consumption

I. INTRODUCTION

For a human being, travelling has become an important part of life. In order to sustain in this world, he must travel from one place to another. It is very essential that his journey takes as less time as possible. Also it should be economical and available easily. To comfort all these problems, 20th century saw many important inventions such as Bicycle, Mopeds, Scooters, Cars, and Trucks etc. But it is only the two wheel-driven vehicle that our project is concerned with because it is a vehicle where enormous modification and development can be done. Excluding bicycle, which is the simplest of all moving machines, all others are fairly complex, heavy and importable. The output of the engine exhaust gas is given to the input of the turbine blades, so that the pressurized air is produced. This power, the alternate power must be much more convenient in availability and usage. The next important reason for the search of effective, unadulterated power is to save the surrounding environments including men, machine and material of both the existing and the next fourth generation from pollution, the cause for many harmful happenings and to reach the saturation point. The most talented power against the natural resource is supposed to be the electric and solar energies that best suit the automobiles. The unadulterated emission-free electrical and solar power, is the only easily attainable alternate source. Hence we decided to incorporate the solar power in the field of automobile, the concept of many Multi-National Companies (MNC) and to get relieved from the incorrigible air pollution.

An attempt has been made in this work by which the exhaust gas is re-utilized with the help of turbocharger arrangement. The output of the engine exhaust gas is given to the input of the turbine blades which results in driving of the compressor and the pressurized air is produced. This compressed air is then supplied to the input of the engine. This setup is implemented in two wheeler engine having a low velocity of exhaust gas. The fuel inside the two stroke engine does not burn properly due to cycle limitations. By considering this drawback, we decided to build a structure which will help in increasing the performance of a two stroke engine. In actual practice, the air fuel ratio of two stroke engine is less compared to the theoretical value (14:1 or 16:1) because of insufficient amount of air in air-fuel mixture. Thus, we decided to increase the actual air fuel ratio by implementing this new concept of turbo-charging to a two stroke engine. The exhaust gas coming from the engine contains pressure as well as heat energy. Due to availability of these two energies, the exhaust manifold gets preheated and the vapour thus contains high power. This power is wasted by passing the exhaust gas to the surrounding. This energy of the exhaust gas can be utilized. This is done by a system called turbo-charger. Turbo-charging is basically providing pressurized air to the engine without mounting any component. It is a fan assembled unit that rotates on the power of air. This power is supplied by the exhaust manifold. Turbo-charging is the system that gives pressurized air to the carburettor. The carburettor adjusts the regulator valve

according to the air need and the use of fuel is decreased. This also increases the mileage by minimizing the fuel to be supplied by increasing the air fuel ratio.

TURBOCHARGER:

The compressor wheel and turbine are mounted on the same shaft. The exhaust gas coming from the engine strikes turbine blades and rotates the turbine. As the turbine rotates, the compressor wheel starts rotating with the same speed as that of turbine. The fresh air from the atmosphere gets sucked inside the compressor and it gets compressed. This compressed air is then supplied to the carburettor and thus increasing air-fuel ratio.

ENGINE:

Internal combustion engines are those heat engines that burn their fuel inside the engine cylinder. In internal combustion engine the chemical energy stored in their operation. The heat energy is converted in to mechanical energy by the expansion of gases against the piston attached to the crankshaft that can rotate. There are only four strokes involved namely the suction, compression, power, exhaust stroke.

SPECIFICATION:

Engine Description	4 Stroke, Air Cooled, DTS-i
Cooling	Air Cooling
Displacement	134.21 cc
Maximum Power	13 HP @ 8500 rpm
Maximum Torque	11.88 Nm @ 6500 rpm
Number of Cylinders	1

TEMPERATURE SENSOR:

Temperature sensor is a device, to measure the temperature through an electrical signal it requires a thermocouple or RTD (Resistance Temperature Detectors). The thermocouple is prepared by two dissimilar metals which generate the electrical voltage indirectly proportional to change the temperature. The RTD is a *VARIABLE RESISTENCE*, it will change the electrical resistance indirectly proportional to changes in the temperature in a precise, and nearly linear manner.

OTHER COMPONENTS:

- 1) Silencer
- 2) Connecting Pipes (CPVC)
- 3) Nut-bolts
- 4) Wheel
- 5) Base Frame

The exhaust gas coming out from turbocharger is send to atmosphere through silencer. We used CPVC pipes for supplying the air from turbocharger to carburettor. The whole set-up is mounted on the base frame by using nut-bolts.

SELECTION OF TURBOCHARGER:

We select turbocharger on the basis of this compressor map which shown in below.

1. Pressure Ratio –Pressure Ratio is defined as the Absolute outlet pressure divided by the Absolute inlet pressure.
2. Mass Flow Rate –Mass Flow Rate is the mass of air flowing through a compressor (and engine!) over a given period of time and is commonly expressed as lb/min (pounds per minute).
3. Surge Line –Surge is the left hand boundary of the compressor map. Operation to the left of this line represents a region of flow instability.
4. Choke Line –It is the right hand boundary of the compressor map.
5. Turbo Speed Lines –This are lines of constant turbo speed. Turbo speed for points between these lines can be estimated by interpolation.
6. Efficiency Islands –This are concentric regions on the maps that represent the compressor efficiency at any point on the map.



Turbocharger Selection Calculations –

• • Maximum RPM

1. Actual air flow required (lb/min) –

$$\begin{aligned} W_a &= HP * A/F * (BSFC/60) \\ &= 18 * 12 * (0.5/60) \\ &= 1.8 \text{ lb/min} \end{aligned}$$

Where:

- W_a = Airflowactual (lb/min)
- HP = Horsepower Target (flywheel)
- A/F = Air/Fuel Ratio
- BSFC/60 = Brake Specific Fuel Consumption

2. Manifold Pressure Required to HP targeted –

$$\begin{aligned} (Map)_{req.} &= w_a * R * (460 + T_m) / V.E * (N/2) * V_d \\ &= 1.8 * 639.6 * (460 + 100) / 0.90 * (8500/2) * 8.237 \\ &= 20.46 \text{ psia(Absolute)} \end{aligned}$$

Where:

- MAPreq = Manifold Absolute Pressure (psia) required to meet the horsepower target
- W_a = Airflowactual(lb/min)
- R = Gas Constant = 639.6
- T_m = Intake Manifold Temperature (degrees F)
- VE = Volumetric Efficiency
- N = Engine speed (RPM)
- V_d = engine displacement (Cubic Inches)

$$\begin{aligned} \text{Gauge Boost Pressure} &= \text{Absolute Press.} - \text{Atmospheric Press.} \\ &= 20.46 - 14.7 \\ &= 5.76 \text{ psia} \end{aligned}$$

3. Compressor Discharge Pressure (P2C) –

$$\begin{aligned} P_{2C} &= Map + \Delta P_{\text{lose}} \\ &= 20.46 + 2 \quad \dots\dots\dots (\text{Assume } 2 \text{ psialoss}) \\ &= 22.46 \text{ psia} \end{aligned}$$

Where:

- P2c = Compressor Discharge Pressure (psia)
- MAP = Manifold Absolute Pressure (psia)
- ΔP_{loss} = Pressure Loss Between the Compressor and the Manifold (psi)

4. Compressor inlet pressure (P1C) –

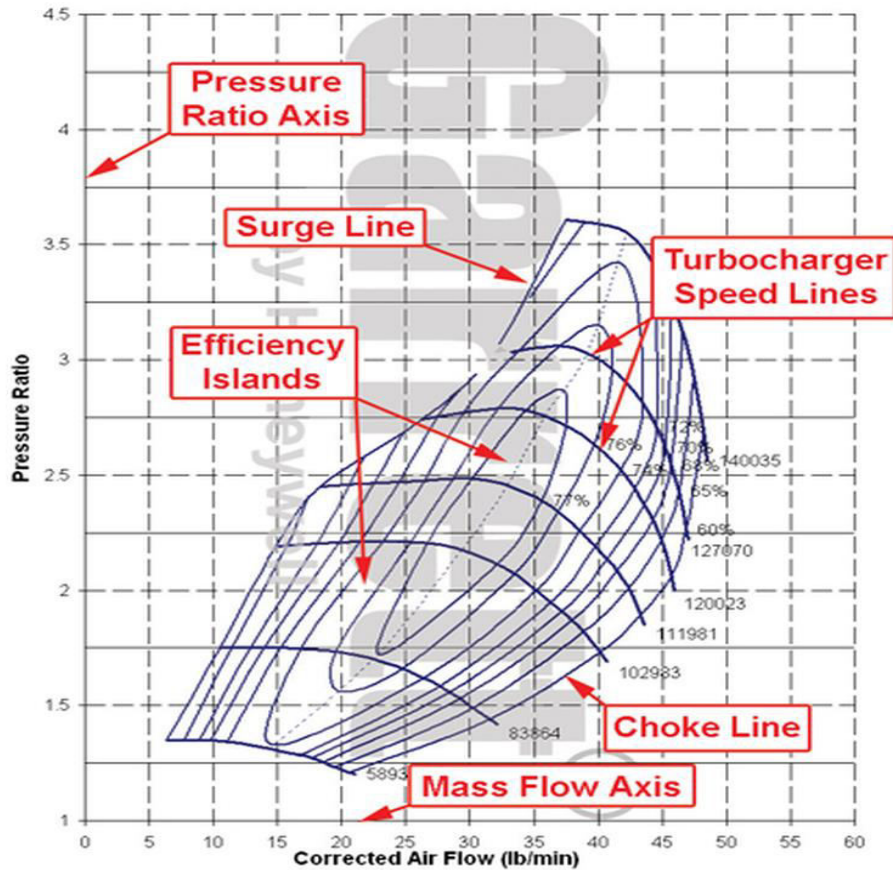
$$\begin{aligned} P_{1C} &= P_{amb.} - \Delta P_{\text{lose}} \\ &= 14.7 - 1 \quad \dots\dots\dots (\text{Assume piping lose} = 1 \text{ psia}) \\ &= 13.7 \text{ psia} \end{aligned}$$

Where:

- P1c = Compressor Inlet Pressure (psia)
- Pamb = Ambient Air pressure (psia)
- ΔP_{loss} = Pressure Loss due to Air Filter/Piping (psi)

5. Pressure ratio –

$$\begin{aligned}
 &= P2C / P1C \\
 &= 22.46 / 13.7 \\
 &= 1.639
 \end{aligned}$$



TESTING & CALCULATION:

1.Engine Performance Testing:

For the engine performance test, take different quantities of fuel and for this run engine till total fuel is consumed. Taking the readings without attaching the turbocharger with engine and engine with turbocharger.



TABLE NO. 1

SR NO.	FUEL QUANTITY (ml)	TRIAL NO.	WITHOUT TURBOCHARGER (sec)	WITH TURBOCHARGER (sec)	INCREASE IN TIME (sec)	% INCREASE IN TIME (%)	AVERAGE INCREASED TIME (%)
1	20	1	85.96	93.91	7.95	9.20	9.77
		2	84.34	93.27	8.92	10.27	
		3	87.4	95.84	8.44	9.83	
2	40	1	167.29	185.00	17.71	10.58	10.53
		2	173.39	191.61	18.22	10.41	
		3	170.78	189.06	18.28	10.61	
3	60	1	253.69	278.81	25.12	9.800000000	9.8

TABLE NO. 2

	RPM	FUEL QUANTITY (Lit)	TIME (SECONDS)	DISTANCE TRAVELLED (km)	INCREASE IN MILEAGE (KMPL)	PERCENTAGE INCREASE IN MILEAGE (%)
WITHOUT TURBOCHARGER	312.80	0.02	85.96	0.2741	1.265	9.230
WITH TURBOCHARGER		0.02	93.91	0.2994		
WITHOUT TURBOCHARGER	375.36	0.02	103.152	0.3947	1.825	9.247
WITH TURBOCHARGER		0.02	112.692	0.4312		
WITHOUT TURBOCHARGER	500.85	0.02	137.637	0.7028	3.25	9.248
WITH TURBOCHARGER		0.02	150.367	0.7678		

From table No.1 :

Fuel consumption = Fuel quantity / Time

1. Fuel consumption rate for 20 ml

I. Without Turbocharger -

$$\begin{aligned} \text{Fuel consumption} &= 20 / 85.90 \\ &= 0.2328 \text{ ml/sec} \\ &= 0.8380 \text{ lit/hr} \end{aligned}$$

II. With Turbocharger -

$$\begin{aligned} &= 20 / 94.34 \\ &= 0.2119 \text{ ml/sec} \\ &= 0.7631 \text{ lit/hr} \end{aligned}$$

$$\begin{aligned} \text{Reduction in fuel consump.} &= \text{fuel consu. (without turbocharger)} - \text{fuelconsump. (with turbocharger)} \\ &= 0.8380 - 0.7631 \\ &= 0.0749 \text{ lit/hr} \end{aligned}$$



2. Fuel consumption rate for 40 ml
 I. Without Turbocharger –

$$\begin{aligned} \text{Fuel consumption} &= 40 / 170.48 \\ &= 0.2346 \text{ ml/sec} \\ &= 0.8445 \text{ lit/hr} \end{aligned}$$

- II. With Turbocharger –

$$\begin{aligned} &= 40 / 188.55 \\ &= 0.2121 \text{ ml/sec} \\ &= 0.7637 \text{ lit/hr} \end{aligned}$$

$$\begin{aligned} \text{Reduction in fuel consump.} &= \text{fuel consu. (without turbocharger)} - \text{fuelconsump. (with turbocharger)} \\ &= 0.8445 - 0.7637 \end{aligned}$$

$$= 0.0808 \text{ lit/hr}$$

3. Fuel consumption rate for 60 ml
 I. Without Turbocharger –

$$\begin{aligned} \text{Fuel consumption} &= 60 / 253.69 \\ &= 0.2365 \text{ ml/sec} \\ &= 0.8514 \text{ lit/hr} \end{aligned}$$

- II. With Turbocharger –

$$\begin{aligned} &= 60 / 278.81 \\ &= 0.2152 \text{ ml/sec} \\ &= 0.7747 \text{ lit/hr} \end{aligned}$$

$$\begin{aligned} \text{Reduction in fuel consump.} &= \text{fuel consu. (without turbocharger)} - \text{fuelconsump. (with turbocharger)} \\ &= 0.8514 - 0.7747 \end{aligned}$$

$$= 0.0767$$

From Table No. 2 :

Mileage (kmpl) = Distance Travelled (km) / Fuel Quantity (lit)

1. @ 312.80 RPM

I. Without Turbocharger –
 Mileage = 0.2741 / 0.02
 = 13.705 kmpl

II. With Turbocharger –
 Mileage = 0.2994 / 0.02
 = 14.97 kmpl

2. @ 375.36 RPM

I. Without Turbocharger –
 Mileage = 0.3947 / 0.02
 = 19.735 kmpl

II. With Turbocharger –
 Mileage = 0.4312 / 0.02
 = 21.56 kmpl

3. @ 500.85 RPM

I. Without Turbocharger –
 Mileage = 0.7028 / 0.02



= 35.14kmpl

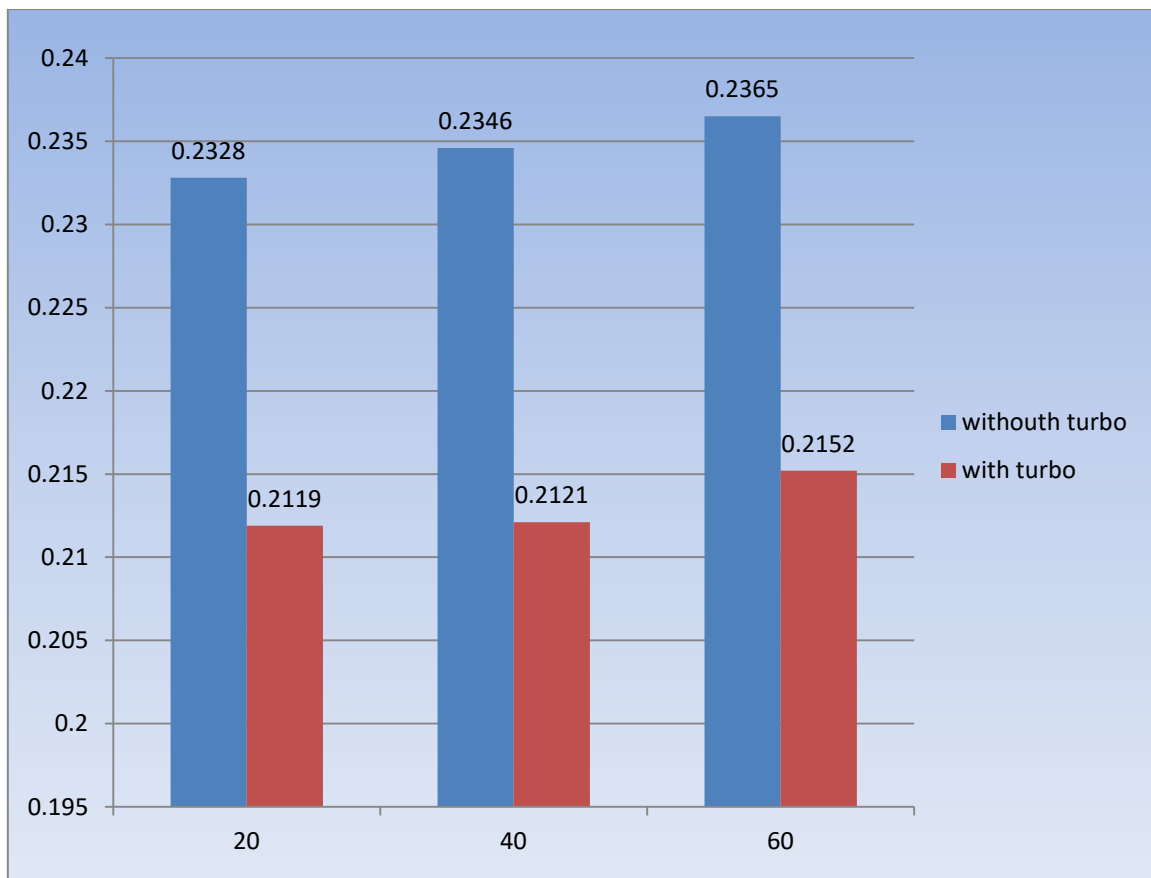
- II. With Turbocharger –
Mileage = 0.7678/ 0.02
= 38.39kmpl

3.Exhaust Gas Analysis

Sr. No.	Emission	Without turbocharger	With Turbocharger
1	HC	1110 ppm	238 ppm
2	CO	0.167 %	0.102 %
3	CO2	3.99 %	3.54 %
4	O2	20.84 %	21.55 %

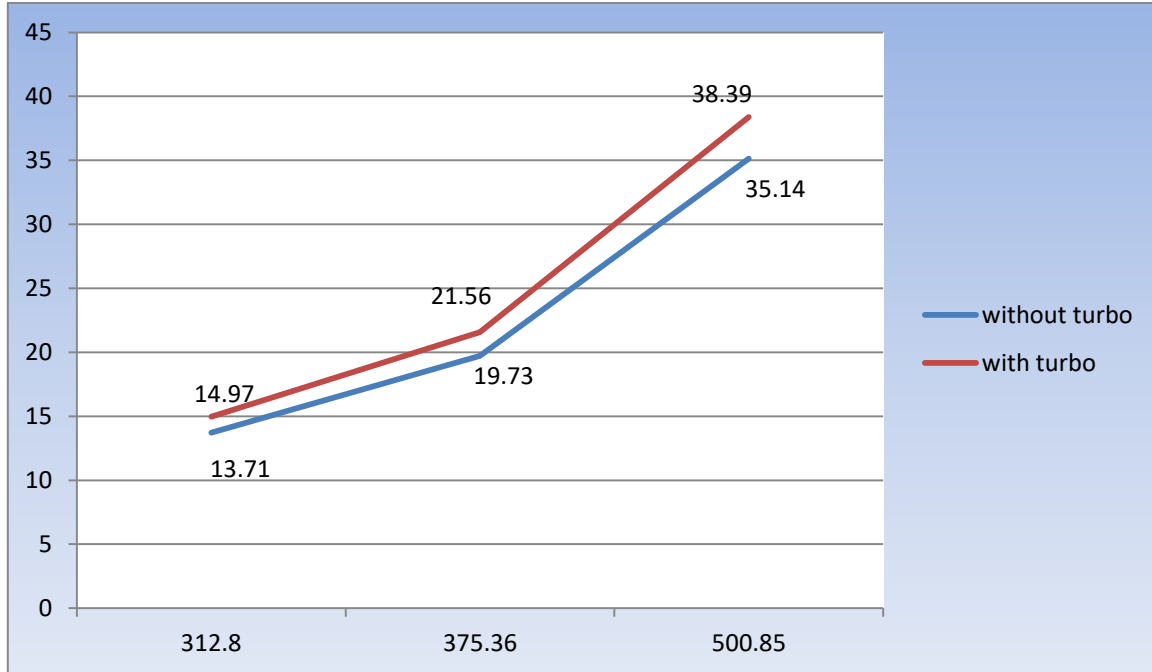
IV. RESULTS & DISCUSSION

1) Fuel quantity (ml) vs fuel consumption rate (ml/sec)





2) RPM VS MILEAGE (kmpl)



From the plots, it is clear that for a given engine speed the fuel consumption is reduced and average increases considerably for the turbocharged engine, than the naturally aspirated base engine. At the same time reduction in the exhaust emissions, especially the CO (%vol), is a clear indication of an improved combustion, due to the presence of increased mass density of air in the combustion chamber after the installation of the turbocharger.

V. CONCLUSION

We have fabricated, and installed prototype of a Turbocharger for the Two- wheeler application. With the analysis of fuel consumption and exhaust gas emissions it is found that the fuel consumption is decreased considerably over all working speeds of the engine, and reduce (CO, HC, CO₂) emissions , At the same time O₂ percentage increases after the installation of the turbocharger indicates a better combustion of fuel due to the added air density during induction. This work is an attempt to fabricate a turbocharged single cylinder, spark- ignition engine two-wheeler.

To conclude, the benefits observed are :

- Improved fuel economy (Reduction in fuel consumption of the base engine).
- Observable reduction in the exhaust emission.

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SJIF Scientific Journal Impact Factor
Impact Factor: 8.118



ISSN INTERNATIONAL
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