Assessment of Turbocharge System for an Existing Gas Engine

Nader A. Nader
Mechanical Engineering Department, Prince Mohammad Bin Fahd University, P.O. Box 1664 Al Khobar 31952
nnader@pmu.edu.sa

Abstract. S Turbocharger is a turbine driven air compressor and forced induction device powered by exhaust gases from the internal combustion engine. A turbocharger consists of two chambers connected by center housing. The two chambers contain a turbine wheel and a compressor wheel connected by a shaft which passes through the center housing. The response of the turbine to the engine exhaust, dictates the response of the compressor and thus the engine air inlet. Turbocharger response time (also known as turbo lag, is directly related to the size of the turbine and compressor wheels. Small wheels accelerate rapidly; large wheels accelerate slowly. While small wheels would seem to have an advantage over larger ones, they may not have enough airflow capacity for an engine. Therefore, to minimize turbo lag, the intake and exhaust breathing capacities of an engine must be matched to the exhaust and intake airflow capabilities of the turbocharger. The results of the current study showed that the horsepower of 347 hp and torque 380 ft-lb before turbocharge reached to 483.3 hp, torque 552 ft-lb after turbocharge at a speed of 4600 rpm.

1. Introduction
Turbocharging innovation is today considered as a promising route for motor vitality sparing and CO2 diminishment. Significantly more noteworthy accentuation of turbocharging innovation is being set on scaling down the motors to expanding efficiency and decreasing CO2 outflows [1]. Transportation framework speaks to 20% to 25% of the CO2 in the environment and this offer tends to increment. Enhancing the proficiency of vehicle inner burning motor power frameworks assumes a basic part in the usage of worldwide vitality preservation and condition security techniques. Progressed turbocharging innovation may decrease the motor dislodging volume while keeping a similar execution regarding torque and power contrasted with the underlying bigger motor, and at the same time guarantees a change in motor effectiveness [2]. Amid the most recent couple of years, a few auto creators have introduced 1.8–2.0 L turbocharged motors. The exhibitions of these turbocharged motors are commonly like those of normally suctioned motors with 2.5 L relocation [3, 4]. The lessening of fuel utilization is normally over 10%, with running conditions nearer to the best proficiency territory. The turbocharging for the scaled back motor could likewise reduce the grating misfortune. Motor turbocharging is the mix of an interior burning motor and a turbocharger. A turbocharger configuration is a noteworthy test for motor execution change. Amid the conventional motor advancement process, the turbocharger is chosen from accessible item records in light of the trademark maps. The picked turbocharger is one of the arrangement items by the part provider, which is outlined and created by the turbo-hardware specialists, and there is an absence of thought of motor task conditions, particularly at the off-plan conditions. Turbocharger configuration ought to be a coordinated method including changing the turbocharger...
qualities into determination of the motor execution to fulfill the motor task necessities [5]. The task of a turbocharger is on a very basic level unique in relation to that of a responding motor, so a turbocharged motor has numerous unpredictable qualities. The turbocharged motor execution is resolved in substantial part by the procedures collaboration amid activity of the turbocharger and the motor, particularly at off-outline tasks. It might well be important to enhance the execution of the mix by turbocharger plan and motorcycle advancements in the meantime, to incorporate new contemplations, streamlining turbocharger outline and motor framework combination, with the thought of general task execution [6].

Figure 1. Turbocharge integrated approach [2]

Several researcher found that turbocharging, notwithstanding expanding a motor's energy yield, can be adequately used to keep up deplete discharge levels while enhancing efficiency. Their work showed that the discharge and execution comes about acquired from a turbo charged multi cylinder start motor with warm reactors and fumes gas distribution (EGR) worked at consistent state, part load conditions for four motor rates [7]. When contrasting a turbocharged motor with a bigger dis arrangement normally suctioned motor of equivalent power output, the outflows communicated in grams per mile were moderately unaltered both with and without EGR. Be that as it may, turbo charging gave a normal of 20% change in mileage both with and without EGR. When contrasting the turbocharged and non-turbocharged forms of a similar motor without EGR at a given load and speed, turbocharging expanded the hydrocarbon (HC) and carbon monoxide (CO) emanations and diminished oxides of nitrogen (NOx) emanations. With the expansion of EGR, turbocharging expanded every one of the three discharges. More detailed studies were found on the discharge attributes of a Volkswagen retrofitted with a turbocharger unit [8]. The turbocharger establishment appeared a slight decrease in discharges, in spite of the fact that whether this was expected to the turbocharger or a distinction in carburetor change is obscure. The adjustments in street execution contrasted with the stock vehicle were emotional. For instance, the turbocharger lessened the 50-80 mph hanging loose from 30 to 20 s, however mileage under street stack conditions remained un-changed. Other paragraphs are indented (BodytextIndented style).
Several researchers stated that the optimum air quantity for minimizing BSFC was studied experimentally on heavy-duty diesel engines under the restrictive conditions of NOx emissions, exhaust smoke, and Pmax [9]. In addition, the performance characteristics of the waste gate control turbocharging, variable geometry turbocharging, sequential turbocharging, and two-stage turbocharging were discussed. In the low engine speed range where the air quantity is insufficient, when the air quantity is increased, Pmax does not increase due to retardation of injection timing while the smoke concentration and BSFC can be reduced substantially. It is therefore advisable to maximize the air quantity as far as possible [10, 11, 12]. The methods to increase the air quantity in the low engine speed will be the waste gate control turbocharging, the variable geometry turbocharging (VGT), the sequential turbocharging, and the two-stage turbocharging. As practical methods, the waste gate turbocharging and VGT were compared with the conventional turbocharging. The waste gate control turbocharging and VGT increase the air quantity in the low engine speed over that of the conventional turbocharging. They are the effective methods for torque recovery in the low engine speed [13]. In the middle and high engine speed ranges, when the air quantity is increased, the smoke concentration and BSFC tend to decrease but its reduction effect is rather insignificant. Over the air excess ratio 2 in the high engine speed range where the air quantity is sufficient, the efficiencies of combustion and gas exchange work cannot be improved even if the air quantity is increased [14]. Moreover, BSFC tends to worsen due to an increase in friction due to the increase of Pmax. Under the present technical limitations, the target value of air excess ratio is around 2. It is therefore important to optimize the air quantity while taking account of the smoke concentration, BSFC requirement, and Pmax limit in the middle and high engine speed ranges [15].

2. Theoretical Calculations

The Brake Mean Effective Pressure, $h_{\text{mep}}$, is given by:

$$h_{\text{mep}} = \frac{4 \pi \tau}{V_d}$$  (1)

The Brake Power, $W_b$, is expressed by:

$$W_b = 2\pi \tau N$$  (2)

The Mean Piston Speed ($U_P$), $U_P=2NS$  (3)

The mass Airflow rate ($m_{\text{a}}$),

$$m_{\text{a}} = e_v \rho_l V_d \left(\frac{N}{\pi}\right)$$  (4)

Density of the air,

$$\rho_l = \left(\frac{P_l}{R T_0}\right)$$  (5)

Figure 2. Turbocharged Engine Installation Schematic [2]
Mass flow rate ($\dot{m}$),

$$\dot{m} = \rho_1 A_f c_o \left[ \frac{2}{\gamma-1} \left( \left( \frac{P_2}{P_1} \right)^\frac{\gamma}{\gamma-1} - \left( \frac{P_2}{P_1} \right)^\frac{1}{\gamma-1} \right) \right]^{\frac{1}{2}}$$  \hspace{1cm} (6)

Speed of sound

$$c_o = \sqrt{\gamma R T_i}$$  \hspace{1cm} (7)

Effective area

$$A_f = C_f A_V = C_f \frac{\pi}{4} d^2 \text{ (seat)}$$  \hspace{1cm} (8)

The Mach number ($M$),

$$\frac{P_3}{P_2} = \left[ 1 + \left( \frac{\gamma-1}{2} \right) M^2 \right]^{\frac{\gamma}{\gamma-1}}$$  \hspace{1cm} (9)

The critical mass ($m_{cr}$),

$$m_{cr} = \rho_1 A_f c_o \left( \frac{2}{\gamma+1} \right) \left[ \left( \frac{\gamma+1}{\gamma-1} \right) \right]^{\frac{\gamma}{\gamma-1}}$$  \hspace{1cm} (10)

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**Figure 3.** Peak Torque and Horsepower Vs RPM.

**Table 1.** Data collection for the car from Excel data log

| Pressure inlet (KPa) | Pressure ratio | Inlet temperature (K) | Volume displacement | Stroke (mm) | Valve diameter (mm) |
|----------------------|----------------|-----------------------|---------------------|-------------|---------------------|
| 101.3                | 0.982          | 301                   | 5.7                 | 90          | 50                  |
3. Design Methodology

To encourage the turbocharger originator to proficiently produce the most appropriate outline, the reason for this exploration is to set up another incorporated plan technique taking into air conditioning include motor cycle necessities the turbocharger improvement process as quickly as time permits. The turbocharger is coordinately planned based on motor cycle advancement and this outline will enhance motor over execution. A 1.8 L fuel motor turbocharger was utilized as a case to represent the improvement of this approach turbocharger through stream display, the geometry and the execution information will be moved into the motor model for cycle execution reenactment. In light of a particular arrangement of motor necessities, the approach will recognize conceivable turbocharger configuration yield parameter esteems that can meet these prerequisites. An enhancing task methodology is then utilized to create plausible plan choices, and after that the focused-on motor arranged turbocharger will be acquired. There are two separate parts of the turbocharger that need to be sized correctly, the compressor and the turbine. However, before either of these components can be sized, the objectives of the turbocharged system need to be determined. While engine displacement and peak horsepower are important pieces of information, further planning is needed before proceeding with the selection of a turbocharger.

![Turbocharger Frame Dimensions](image)

**Figure 4. Sizing of Turbocharge**

A waste gate is a boost-controlling device that operates by limiting exhaust gases going through the turbocharger, controlling the maximum boost pressure produced by the turbocharger itself. A waste gate consists of an inlet and outlet port, a valve and a pressure actuator. A pressure actuator, controlled by boost pressure determines whether the waste gate is open or shut. In its resting position, a waste gate is shut, and as the boost pressure builds, force is applied to the actuator. When the boost pressure exceeds the spring value, the actuator will progressively open the waste gate, bypassing some of the exhaust...
gases therefore maintaining the boost pressure at the set level. To put it simply – a waste gate prevents the boost pressure from climbing indefinitely and consequently blowing the engine. The location of the waste gate under turbocharge fixed on exhaust pipe.

4. Experimental Work
In the beginning, put the car on the dynamometer and strapping it on the dynamometer by using ropes installed in the ground to prevent the car from sliding or deflecting from the dynamometer. After that, connect the computer of the car by the tuner computer to programme and put new set up for the car. Then, accelerate the car by passing the gear until the fourth gear, on the fourth gear the tuner presses the entire throttle until the car takes its maximum speed. Figure five below shows the design assembly, the block of engine, exhaust, intercooler, wastegate, turbocharger, cold inlet pipe, blow off valve, Intake, hot air inlet and cold blow off valve. In figure (6) shows the center section, comp. housing, back plate, comp wheel, O ring, thrust ring, comp bracket, thrust, center O ring, oil bearing, turbine shield, turbine wheel, turbine wheel nut, back plate bolt, Bearing clip, clip, bearing, turbine housing and turbine bracket.

![Figure 5. Assembly of Engine (SOLIDWORKS)](image)
The connections for all inlets and outlets were examined. The compressor inlet and outlet hose were selected according to standards. The bearings section were maintained and checked for at oil inlet and outlet. These inlets and outlets were tested to determine how easy it would be to acquire and connect the right hoses for the oil and, possibly, water. The oil inlet and outlet absolutely were not on the same face. The same was true for the water inlet and outlets. If the inlet and outlet are on the same face, the small size of the turbocharger can create major problems in fitting all the necessary connections into that small area. The turbine inlet and outlet were bolted on connections requiring flanges. Preferably the turbocharger manufacturing will produce gaskets and flanges for the turbine, which saves the trouble of having to design and machine custom ones. Thicker flanges and flange connections seal better and are less likely to fail under the stress they experience. The intercooler’s job is to cool down the air after it has been compressed by turbocharge, but before it enters the engine. Turbochargers work by compressing air, increasing its density before it reaches the cylinders of the engine. By squeezing more air into each cylinder, the engine is able to burn proportionally more fuel, creating more power with each explosion. The intercooler works to counteract this process, cooling the compressed air to provide the engine with more oxygen, and improving the combustion in each cylinder. In addition, by regulating the temperature of the air, it also increases the reliability of the engine, by ensuring the air to fuel ratio in each cylinder is maintained at a safe level.
5. Results and Discussion

The results, the horsepower and torque vs. rpm are shown in figure 7. for the turbocharge. Moreover, an increase in the torque was visible with increase in speed. The maximum horsepower is 347 hp at 5200 rpm, and the maximum torque is 380 ft-lb at 4250 rpm. In addition, after installing turbocharge, a significant increase was obtained in both the horsepower and torque.

Figure 7. RPM VS Horsepower & Torque before Turbocharge

Figure 8 shows the relation between horsepower and torque together versus rpm before turbocharge. Both horsepower and torque are increasing and that is good indicator to make sure that the dynamometer work well.

Figure 8. Dynamometer after Turbocharge
Figure 9, shows the relationships between horsepower and torque together versus rpm after turbocharge. Both horsepower and torque are increasing and that is good indicator of making sure that the dynamometer is working correctly. After installing turbocharge on the car and after repeated testing, the system was working according to the design parameters and good results were gathered for the horsepower and torque as shown in the figure 9. The results before turbocharge was horsepower 347hp, torque 380 ft-lb and after turbocharge was horsepower 483.3 hp, torque 552 ft-lb.

6. Conclusion
This study was to assess and design a turbocharge system for an existing engine. Many components were designed manufactured and assembled to complete the work of this study. Usage of better material such as aluminum instead of the stainless steel can improve better the heat transfer, weight and thus better performance. Nevertheless, the cost will be more expensive in order to ensure such superior performance. On the other hand, the size of the turbocharge and compatibility issue with the engine plays an important role in improving the optimum performance requirements. The results of the current study showed that the horsepower of 347hp and torque 380ft-lb before turbocharge reached to 483.3 hp, torque 552 ft-lb after turbocharge at a speed of 4600rpm.

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