Effects of Turbo Charging of Spark Ignition Engines

Aman GUPTA[1], Sunny NARAYAN[2]

[1] Indus University, India, sn2008@rediffmail.com

[2] Indus University, India, rarekv@gmail.com

Abstract: *Turbocharging is an important method that is aimed at achieving maximum mechanical efficiency & fuel-economy, both simultaneously in automobiles. The principle objective of turbo charging is to increase the power output per volume and cost of engine. A fact that a turbocharger increases the mass of air in the cylinder and consequently allows more fuels to be burnt, improves the volumetric efficiency of the engine and simultaneously improves engine efficiency by a small but worthwhile amount. Turbochargers are commonly being used on diesel engines for many years. In contrast only a few petrol engines have been turbocharged until recently and it is unlikely that a large fraction of the world petrol engine will be so equipped. There would be a tremendous growth in demand of Gasoline downsizing, in next few years. The present work aims at analyzing the various benefits associated with Turbo charging in SI engines and designing it for future automotive engines. Design calculations were performed to compare improvements in performance of engine with and without turbocharging which highlight the advantages of turbocharging process.*

Keywords*: S.I. Engines, Turbo charging*

1. Introduction

A turbocharger basically consists of a compressor and a turbine coupled on a common shaft [1].The exhaust gases from the engine are directed by the turbine inlet casing on to the blades of the turbine and subsequently discharged to atmosphere through a turbine outlet casing [2].The exhaust gases are utilized in the turbine to drive the compressor, which compresses the air and directs it to the engine induction manifold, to supply the engine cylinders with air of higher density than is available to a naturally aspirated engine [3]. The higher value of air-pressure achieved using a turbo-unit is called Boost-pressure [4].There exist a number of different types of compressors and turbines, but few of these are ideally suitable to form the basis of an exhaust gas driven supercharging system. The combination of a single stage centrifugal compressor and a single stage axial flow or radial flow turbine is almost universally used in turbochargers [5].The former type is used for medium and large size engines, while the latter type is used for small engines of automotive type.
Some merits of this technology include:
1. Increase the fuel volumetric efficiency by about 30% to 40%.
2. Increase the number of power stroke i.e. increase the final output.
Some demerits include:
1. A disadvantage of turbo charger is its resistance to high temperature at high load, which imposes to increase equivalent ratio (enrichment).
2. The main disadvantage in the turbine inertia and the corresponding long response time needed to obtain the supercharging pressure.

2. Turbocharging in S.I. engines

In SI engines, fuel and air are pre-mixed before the air enters the cylinder of petrol engine. Whether a carburetor or manifold petrol injection system is used, cylinder comprises of homogeneous air and fuel mixture, the proportion of fuel being carefully controlled [6].The homogeneous mixture is ignited by the spark plug. Unlike diesel engine the rate at which combustion proceeds is governed by heat and mass transfer from an area that is burning to an area that is not, and temperature increase due to continued compression thus flame advances across the combustion chamber, from the spark plug until all the fuel is burned [7].

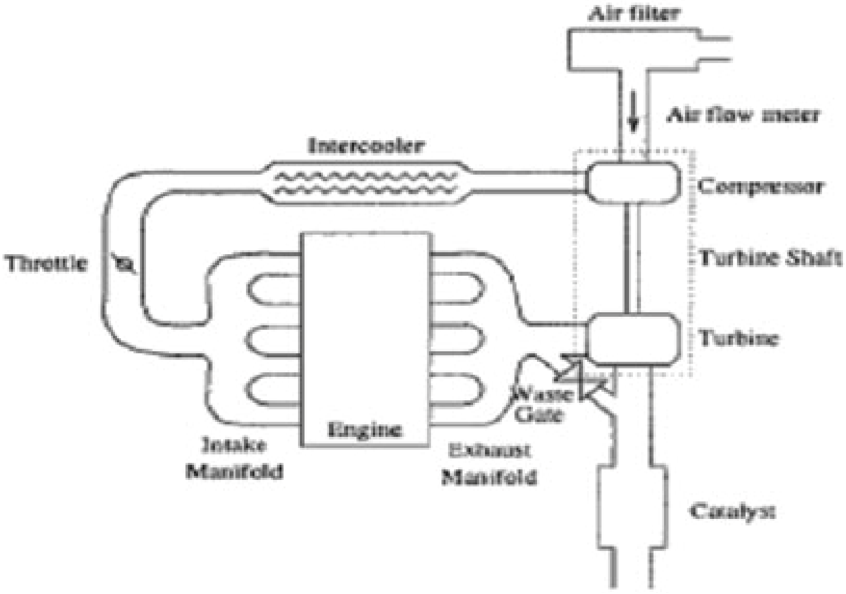

Fig. 1. Sketch of a turbocharged SI-engine

Self ignition is avoided by low compression ratios, enough to hold the temperature of mixture below the self ignition point of the fuel, and by self ignition temperature [8]. The rate at which the flame progresses is governed by local turbulence, heat transfer between burning and unburned region, compression heating of the unburned gas due to piston motion and expansion of burning mixture, air/fuel ratio and heat transfer to the surrounding walls [9]. Since the unburnt gas that is removed from the advancing flame front is heated by compression and to some extent by radiation etc. [10].This gas can reach its self ignition temperature before the flame front arrives, thus increasing the chances of knocking in the end gas region 11].This extremely rapid combustion generates a high rate of pressure rise in the cylinder, the impulse of force causing the bearing to knock, generally referred to as detonation [12].

3. Parts of Turbocharger

3.1 Turbine [13]

The turbine wheel is made from a high nickel super-alloy investment casting. This method produces accurate turbine blade sections and forms. Larger units are cast individually. For smaller sizes the foundry will cast multiple wheels using a tree configuration.

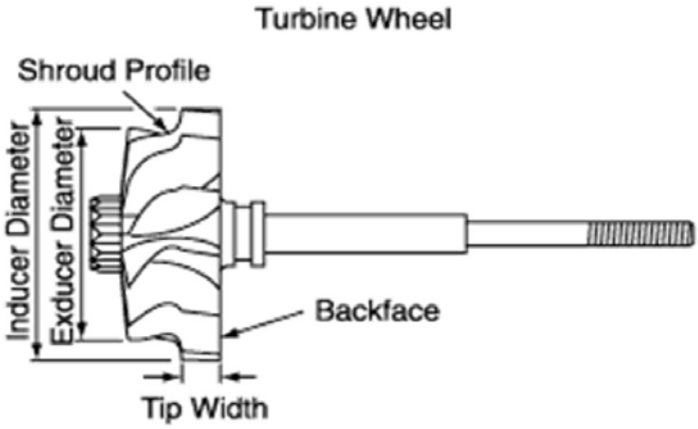

Fig. 2. Sketch of a turbine wheel

3.2 Compressor [14]

Compressor impellers are produced using a variant of the aluminum investment casting process. A rubber former is made to replicate the impeller around which a casting mould is created. The rubber former can then be extracted from the mould into which the metal is poured. Accurate blade sections and profiles are important in achieving compressor performance. Back face profile machining optimizes impeller stress conditions. Boring to tight tolerance and burnishing assist balancing and fatigue resistance. The impeller is located on the shaft assembly using a threaded nut.
Compressor housings are also made in cast aluminum (cast iron for high-pressure applications). Various grades are used to suit the application. Both gravity die and sand casting techniques are used. Profile machining to match the developed compressor blade shape is important to achieve performance consistency.

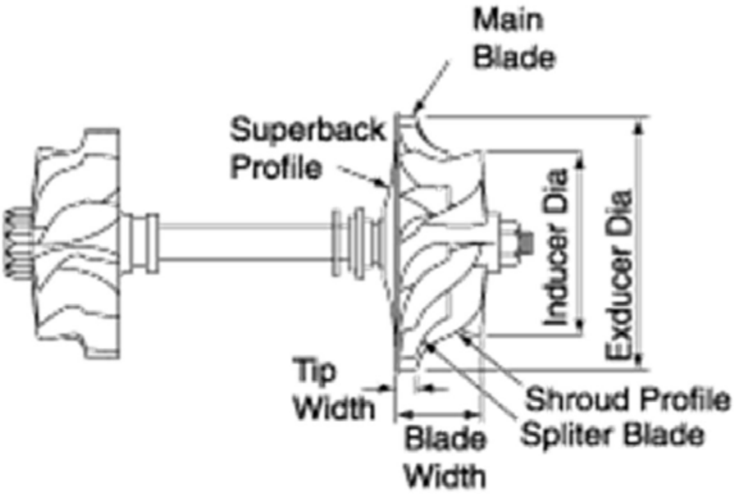

Fig. 3. Sketch of a compressor wheel

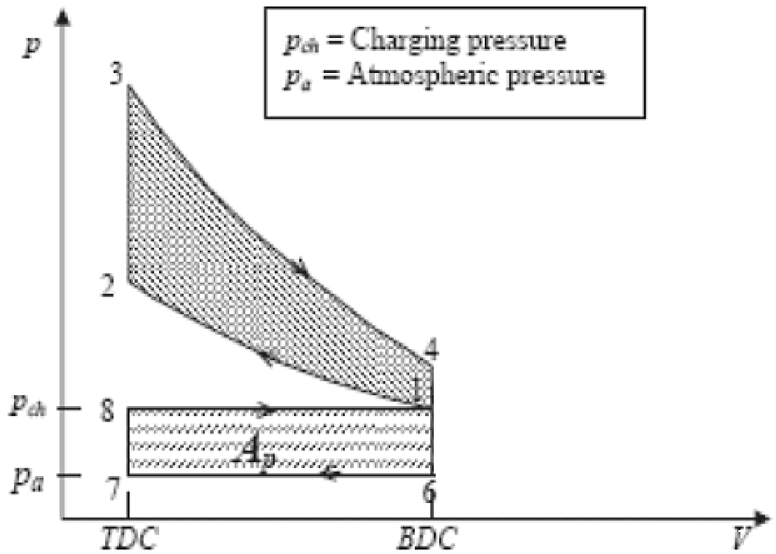

Fig. 4. Sketch of a P-V curve turbocharged SI-engine

4. Conclusion

This work compares the engine performance of a spark ignition engine with and without use of turbocharging system. A decrease in specific fuel consumption is observed with increased torque output and thermal efficiency.
In the 1980s, turbocharged cars were difficult to handle. The tuned engines fitted to the cars, and the often primitive turbocharger technology meant that power delivery was unpredictable and the engine often suddenly delivered a huge boost in power at certain speeds.. As turbocharger technology improved, it became possible to produce turbocharged engines with a smoother, more predictable but just as effective power delivery.
Today, turbo charging is most commonly used on two types of engines: Gasoline engines in high-performance automobiles and diesel engines in transportation and other industrial equipment. Small cars in particular benefit from this technology, as there is often little room to fit a larger-output (and physically larger) engine.
In future, to meet U.S. emission regulations, injector systems will have to be optimized with increased functionalities, multiple injection strategies and increase pressures (up to 2000 bars or more). However improved combustion systems will have to be supplemented with after - treatment techniques like selective catalytic reduction (SCR) for NOx reduction and state of art particulate filters.
Turbo charging would be adopted much faster in downsized engines for entry level vehicles, on account of their low costs.

References

[1] Payri F, Serrano JR, Piqueras P, García-Afonso O. ,"Performance analysis of a turbocharged heavy duty diesel engine with a pre-turbo diesel particulate filter configuration", SAE Int J Engines 2011;4(2):2559-72;
[2] Bermúdez V, Luj_an JM, Piqueras P, Campos D., "Pollutants emission and particle behavior in a pre-turbo aftertreatment light-duty diesel engine", Energy, 2014;66:509-22;
[3] Bermúdez V, Serrano JR, Piqueras P, García-Afonso O. ,"Assessment by means of gas dynamic modelling of a pre-turbo diesel particulate filter configuration in a turbocharged HSDI diesel engine under full-load transient operation", P I Mech Eng D-J Aut 2011;225(9):1134-55;
[4] Serrano JR, Arnau FJ, Dolz V, Piqueras P.," Methodology for characterization and simulation of turbocharged diesel engines combustion during transient operation. Part 1: data acquisition and post-processing", Appl Therm Eng 2009;29(1):142e9;
[5] Payri F, Benajes J, Galindo J, Serrano JR.," Modelling of turbocharged diesel engines in transient operation. Part 2: wave action models for calculating the operation in a high speed direct injection engine", P I Mech Eng D-J Aut 2002; 216:479-93;
[6] Serrano JR, Climent H, Piqueras P, Angiolini E.," Analysis of fluid-dynamic guidelines in diesel particulate filter sizing for fuel consumption reduction in post-turbo and pre-turbo placement", Appl. Energ. 2014;132:507-23;
[7] Jenny E, Hansel J, Mayer A.," The transient behavior of supercharged passenger car diesel engines fitted with particulate traps", In: SAE Technical Paper890171; 1989;
[8] www.openwam.org;
[9] Serrano JR, Arnau FJ, Dolz V, Tiseira A, Lejeune M, Auffret N.," Analysis of the capabilities of a two-stage turbocharging system to fulfill the US2007 antipollution directive for heavy duty diesel engines", Int J Automot Techn 2008;9(3):277-88;
[10] Hiereth H.,"Car tests with a free-running pressure-wave charger -A study for an advanced supercharging system", In: SAE Technical Paper 890453; 1989;
[11] Tourlonias P, Koltsakis GC. ,"Model-based comparative study of Euro 6 diesel after treatment concepts, focusing on fuel consumption", Int J Engine Res, 2011;12:238-51;
[12] Serrano JR, Guardiola C, Piqueras P, Angiolini E. ,"Analysis of the after treatment sizing for pre-turbo DPF and DOC exhaust line configuration", SAE Tech Pap 2014-01-149;
[13] Dragomirescu A., "Configurations of flow induced by a fan impeller without impeller casing", Hiraulica no 3, 2015;
[14] Budea S., Simionescu S., "Numerical simulation of viscous fluid flow by sealing labyrinth", Hiraulica no 1, 2014.