ISSN 2395-1621

Turbocharging of IC engines to save fuel consumption

#1Mr. N.D. Patil ,#2Mr. N.V. Hargude ,#3Mr. N.S. Mane

1nitin.patil11@rediffmail.com
2nvhargude@gmail.com
3manenikhil24@gmail.com

#123Assistant Professor PVPIT Budhgaon

ABSTRACT

Engines were sole power producing devices for many decades. Today, everyone wants cars that are less harmful to the environment and have better fuel economy. As a small engine use less fuel, it is easy to save fuel by making the engine smaller. However, a small engine does not meet the power expectation of the driver during e.g. over takings. The maximum power of the engine depends on the amount of fuel it can burn and this in turn depends on the availability of air. Thus, more air is necessary to increase the engine power. One way to increase the air to the engine is to add a turbocharger (TC) that simply raises the pressure of the air.
This paper presents turbocharger performance for different conditions in IC engine and turbocharger installation on different type of engines and vehicles.

Keywords: **IC Engine, Turbocharging, Air Fuel ratio**

ARTICLEINFO

Article History :

Received:2nd November 2015

Received in revised form:4th November 2015

Accepted : 5th November 2015

I. INTRODUCTION

Turbochargers are used to increase the maximum power that can be obtained from a given displacement engine. The work transfer to the piston per cycle, in each cylinder, which controls the power the engine can deliver, depends on the amount of fuel burned per cylinder per cycle. This depends on the amount of fresh air that is inducted each cycle. Increasing the air density prior to entry into the engine thus increases the maximum power that an engine of given displacement can deliver. The turbocharger, a compressor - turbine combination, uses the energy available in the engine exhaust stream to achieve compression of the intake flow.

I. TURBOCHARGER

Turbocharger is the mechanical device which increases density of air entering into the combustion chamber of IC engine with compressor which is driven by a turbine driven by exhaust gas of same IC engine. Turbocharging increases quantity of air entering into the combustion chamber which promotes lean combustion, this further result into better performance and lower exhaust emissions. From last few years many researchers made effort to improve the power output of an engine and to reduce exhaust gases by making some changes in conventional turbocharger and installing some additional accessories like turbocharger and intercooler. Due to increase in the demand of fuel efficient engines with more power and minimum emissions more research will take place in this field. All these new requirements of IC engine can be fulfilled by making some advancements in turbo charging technology. Fig 1 shows typical turbocharger installed on a IC engine.

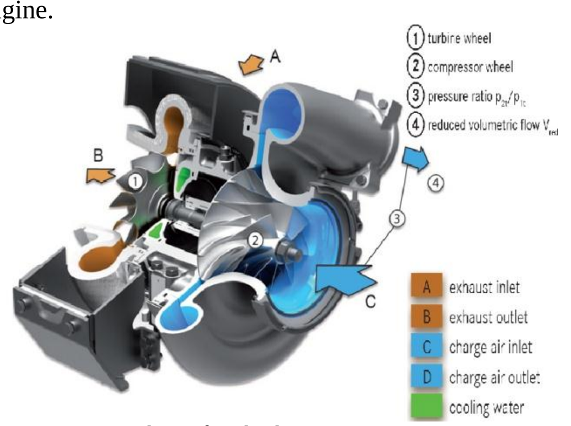

Fig. 1 Working of Turbocharger
(Fig adopted from www.mtu-online.com)

Fig 1 gives an idea about working of turbocharger. The exhaust gas of IC engine is a useful resource and it is capable of producing a useful gain in engine power. Use of turbocharger in IC engine also lowers the operating cost by reducing the fuel consumption.
A turbocharger consists of a compressor and turbine mounted on a common shaft. It is installed on an engine for the purpose of increasing power density of that engine. The working principle of turbocharger is simple; in this the exhaust gas energy of the engine drives the turbine, as the compressor and turbine are mounted on a same shaft compressor also start to rotate. As compressor starts to rotate, it compresses the air which is fed to the engine. This turbine compressed the air that went on to the combustion chamber, thus ensuring a bigger explosion and an incremental boost in power. The fuel-injection system, on its part, made sure that only a definite quantity of fuel went into the combustion chamber.

II. LITERATURE REVIEW

A literature review is conducted on various areas if IC engines and turbochargers and following findings are made;

Powell et al. [1] discuss the application of linear observer theory to engine control with a specific focus on observers based on exhaust measurements. The interesting aspects of the application of observed based control to engine air fuel ratio control are twofold 1) there is pure delay between the plant and the sensor due to the engine cycle and exhaust transport time and 2) the primary disturbance is the throttle which can be measured if a drive by wire throttle incorporated.

Muske et al. [2] presents an adaptive state space model predictive controller for SI engine air fuel ratio control is developed. The time varying delays inherent in this system are accounted for by adapting the time delay of the model based on the engine speed and load. This feature allows the controller to be aggressively tuned at all engine operating conditions.

Rahman et al.[3] investigates the effects of Air-fuel ratio and engine speed on engine performance of Hydrogen fueled, port fueled, port Injection internal combustion engine.GT-power is utilized to develop the model for port injection engine. One dimensional gas dynamics represented the flow and heat transfer in the components of engine model. Air-fuel ratio was varied from stoichiometric limit to lean limit and the rotational speed varied from 2500to 4500 rpm while the injector location was fixed in the midway of intake port.

Geok et al. [4] investigates the performance and emission of a sequential port injection natural gas engine. The engine was converted to computer integrated CNG-gasoline bi-fuel operations by installing a sequential port injection CNG conversion system. Engine control unit and exhaust gas analyzers were used for controlling engine operations and recording engine performance and emission data.

Naser et al., [5] concluded that efficient way which was used that time was to reduce the fuel consumption was based in reduction cylinder volume of internal combustion engine and power to be same or higher. Key component was turbocharged diesel internal combustion engine. Increased compressor outlet air pressure can result in an excessively hot intake charge, significantly reducing the performance gains of turbo charging due to decreased density. Passing charge through an intercooler reduced its temperature, allowing a greater volume of air to be admitted to an engine, intercoolers have a key role in controlling the cylinder combustion temperature in a turbocharged engine. The author, through his worked out programmed code in MATLAB presented effect of intercooler (as a heat exchange device air-to-liquid with three different size and over – all heat transfer coefficient and one base) at multi-cylinder engine performance for operation at a constant speed of 1600 RPM. Author concluded that maximal temperature in engine cylinder was decreasing from 1665.6 K at SU =1000 to 1659.2 K at SU(surface area*heat transfer coefficient)=1600, sometimes engine power and volumetric efficiency was increased. Also intercooler performance was increased with increased the design parameter.

Eyub et al., [6] said that there are mainly three concerning problems present in automobile industry i.e. environmental effect, cost and comfort problems. Therefore, internal combustion engines were required to have not only a high specific power output but also to release less pollutant emissions. For these reasons, that time light and medium duty engines were being highly turbocharged because of having negative environmental effects of internal combustion engines. Due to mentioned facts, there were studies going on to improve internal combustion engine performance. Studies for supercharging systems were also included in this range. One of the most important problems faced in supercharging systems was that air density was decreasing while compressing air. Also air with high temperature causes pre ignition and detonation at spark ignited engines. Various methods were developed to cool down charge air which was heated during supercharging process. One of these methods was to use a compact heat exchangers called as intercoolers to cool charging air. The purpose of an intercooler was to cool the charge air after it has been heated during turbo charging. As the air is cooled, it becomes denser, and denser air makes for better combustion to produce more power. Additionally, the denser air helps reduce the chances of knock. The inter-cooling concept was introduced and performance increase of a vehicle by adding inter-cooling process to a conventional supercharging system in diesel or petrol engine was analytically studied. Pressure drops, air density and engine revolution were used as input parameters to calculate the variation of engine power output. Also, possible downsizing opportunities of the cylinder volume were presented. It was found that the engine power output can be increased 154% by ideal intercooler while single turbocharger without intercooler can only increase 65%. Also a meaningful 50% downsizing of the cylinder volume possibility achieved by means of turbo charging and inters cooling.

Shankar et al. [7] investigates the MPFI gasoline engine combustion, performance and emission characteristics with LPG injection. The work has been carried on four cylinder multiport fuel injection gasoline engine combustion, performance and emission characteristics which are retrofitted to run with LPG injection. This experiment suggests that higher thermal efficiency and therefore improved fuel economy can be obtained from SI engines running on LPG as opposed to Gasoline.

Wladyslaw et al., [8] studied that the main problem in charged spark ignition engine was control of air-fuel ratio near stoichiometric values at different boost pressure in order to obtain higher torque at the same level of specific fuel consumption and exhaust gas emission. Charging of such engine was connected with the problem of knock in the medium and high values of load at low engine speeds. Higher boost pressure leads to abnormal combustion process and to knocking. Author described the boost pressure control algorithm which enables to prevent the knock, so the engine can work near the knock boundary. Medium capacity engine Toyota Yaris 1300 cc SI engine for experimental test was equipped with variable turbine geometry (VTG) turbocharger with possibility to control mass flow rate in the turbine by using additionally waste gate(WG) system. Such approach enabled charging of the engine in wide range of rotational speeds and loads. Special computer control program in Lab view environment was written in order to analyze knock signal and regulate the opening of VGT and WG in dependence on throttle opening (engine load). High voltage of knock signal was given to the electronic control unit (ECU), where was transformed by fast Fourier transform (FFT) procedure, which gave a distribution of knock signal in the range 2000-8000 Hz. Control signal from “knock” was obtained in the range 0 – 0.01 V and was transferred to the control unit for regulation of mass flow rate of exhaust gases through the turbine by VGT and WG. When output signal from FFT was greater than 0.01 V then the valve in WG was opened much more in order to reduce mass flow rate of exhaust gases through the turbine, which decreased rotational speed of the turbocharger and thus decreased pressure ratio behind the compressor.

III. CONCLUSION

It is observed that the existing studies on turbochargers shows positive influence of turbocharger on IC engine power characteristics as well as emission characteristics. But in turbocharging air fuel ratio is always constant, So there is scope to vary the air fuel ratio and find out which is the best suited air-fuel ratio and that can be optimized in this study.

Combustion analysis using the variation of air-fuel ratio, have received the lower attention than ignition analysis, and there is further scope for the combustion analysis, by variation of air-fuel ratio using the turbocharger. Hence this area needs more attention, especially from lean burn combustion.

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