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REVIEW ON TURBOCHARGING OF IC ENGINES

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ABSTRACT

As a demand of new efficient and eco friendly engines is increasing new technologies are developing. Due to rich air fuel mixture combustion emissions will be increased hence by turbocharging the engine more power can be generated with low environmental emissions. In this paper review on various applications of turbocharging technology is made. The behavior of IC engine with application of Turbocharger and need of turbocharger installation is studied in this paper. This paper presents different types of turbochargers, their performance for different conditions in IC engine and turbocharger installation on different type of engines and vehicles.

KEYWORDS: IC Engine, Turbocharging, Air Fuel ratio

INTRODUCTION

SI engines are mechanical devices that generate work using the products of combustion as the working fluid rather than as a heat transfer medium. In SI engine combustion is carried out under high pressure and combustion products are allowed to expand through a piston to produce mechanical work. IC engines are used in thousands of applications in transport and industrial sector. Also, IC engines are major consumers of fossil fuels.
Depletion of fossil fuels and environmental degradation are the main problems of the world in 21st century. Automobile sector is the main source of exhaust gas emission and consumption of fossil fuels because of IC engines. Hence there is requirement of new eco friendly and energy efficient IC engines. Out of many technologies Turbocharging is the promising technology to save fuel and to decrease emissions from IC engines.

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.

TYPES OF TURBOCHARGERS

According to use, requirement and type of engine turbochargers are divided into following types,

- **Gasoline Turbocharger:**

Gasoline (Petrol) Turbocharger is similar to that of diesel engine turbocharger in its working. However, the materials used are special and will have additional features like water cooled bearing housing and recirculation valve to meet specific gasoline engine operating requirements.

- **Non Waste gated Turbocharger :**

This is a basic Turbocharger without boost control. It is mainly used in Industrial and off-highway engines and in some commercial vehicles.

- **Waste gated Turbocharger:**

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It is a turbocharger with maximum boost pressure control. It is currently used in Passenger cars and commercial vehicles.

- **Turbocharger with integrated exhaust manifold:**

The Engine exhaust manifold and turbine housing of this turbocharger is made in single piece. This eliminates joints and facilitates ease of assembly onto the engine.

- **Variable Turbine Geometry Turbocharger:**

Variable Turbine Geometry (VTG) Turbocharger provides boost on demand due to its unique control mechanism. Mainly used in new generation Passenger cars and Vehicles meeting BS IV and above Emission norms.

- **Regulated two stage Turbocharger:**

Regulated two stage Turbocharger (R2S), this system uses one low pressure turbocharger and one high pressure turbocharger i.e. two turbocharger for one engine to obtain high density power. This system offers possibility in downsizing the engine to meet future Emission norms while meeting the customer drivability requirements.

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

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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.

Meyer et al. [9] presents unified exhaust gas oxygen (EGO) based air-fuel ratio control architecture built on a switching frequency regulation design. The switching period control architecture presented in this paper extracts amplitude information from exhaust gas oxygen sensor by analyzing the switching period.

Kusztelan et al., [10] In this study, one-dimensional analysis using AVL Boost software was done on a series of diesel and petrol engines equipped with single entry turbocharger and a modified twin-entry variety, the latter adopting two turbine housing inlet ports. The model reconstruction using AVL Boost considers parameters that accurately represent the physical engine conditions including manifold geometry, turbocharger flow maps and combustion chamber characteristics, etc. Model validations have been made for a manufacturer single-entry turbocharger configuration to predict the maximum engine power and torque, in comparison with available manufacturer data and analytical calculations. Further studies concentrate on engine performance comparisons between single- and twin-entry turbochargers in terms of torque, shaft speed and compressor efficiency and at low engine speed conditions typically in a range of 1000-3000 RPM. It was found that on average engine response has been increased by 27.65%, 5.5%, 5.5% in terms of turbine shaft speed, engine power and torque, respectively, which implies improved "drivability" of the vehicle. This study reveals the potential benefits of adopting a twin-entry turbocharger and the findings would be useful for both industry and academic communities.

Postma et al. [11] investigates the air-fuel ratio control of S.I. Engine using a linear parameter varying controller (LPV) to regulate the air fuel ratio. In order to compensate for air flow changes and maintain a desired air-fuel ratio, the engine control unit adjusts the fuel flow by changing the fuel injector signal pulse width.

Muqeem [12] The objective of a turbocharger is to improve an engine's volumetric efficiency by increasing the density of the intake gas (usually air, entering the intake manifold of the engine). When the pressure of the engine's intake air is increased, its temperature will also increase. Turbocharger units make use of an intercooler to cool down the intake air. Here, the purpose of author was to bring the temperature of intake air nearer to the ambient temperature. The inter-cooling of intake air was greatly increased by installing a specially designed intercooler in which air run as hot fluid and refrigerant, of the air conditioning system coming from cooling coil fitted in the dashboard, run as cold fluid. The intake air is cooled down by the air flowing through the fins of the intercooler and the refrigerant coming from the evaporator. Here the author concluded that when normal air cooled intercooler is used to cool down the hot air before entering into the engine cylinder, the mass of oxygen being fed to the engine becomes 1.43 times but when refrigerated intercooler is used, it becomes 2.618 times. Increasing the oxygen content with the air leads to faster burn rates and the ability to control exhaust emissions. Added oxygen in the combustion air offers more potential for burning diesel.

CONCLUSIONS

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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