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Forced Induction Technologies in an IC Engine: A Review

Ranaji Arib Hafiz Ayyub Akbar Ahmedi
PG Student, Heat Power Engineering Department, Shri Shankarprasad Agnihotri College of Engineering, Wardha, India

Abstract: ***This study has been undertaken to show the performance enhancement of engines using different Forced induction technologies. Forced induction technology like turbocharging and supercharging can enhance the performance of an internal combustion engine by compressing inlet air charge, allowing full engine power to be produced efficiently. As the fuel economy and greenhouse emission standards are projected to be far more stringent globally, the use of a Forced induction engine in passenger cars and light-duty trucks has become an inevitable trend within the automotive industry. A turbocharger system can effectively improve the power and torque of an engine, but turbo hysteresis exists. A mechanical supercharging system can boost at low speed, but the efficiency is lower. An electric supercharger can effectively improve the intake air at the early stage of accelerated working conditions, however, an electric supercharger will consume the engine power. The addition of Forced induction technologies to an IC engine helps with the scope of downsizing it. This review brings forward all the aspects of Forced induction technologies***

Keywords: Forced Induction, Internal Combustion Engine, Turbocharging, Supercharging, Downsizing, Efficiency & Horsepower

I. INTRODUCTION

Forced induction technology enhances the performance of an internal combustion engine by compressing inlet air charge, allowing full engine power to be produced efficiently. Forced induction technology includes methods like turbocharging and supercharging. An engine without forced induction is a naturally aspirated engine. Forced induction is employed within the automotive and aviation industry to extend engine power and efficiency. A forced induction system will increase an internal combustion engine's efficiency and power by forcing extra air into the combustion chamber. This improves over a naturally aspirated engine's power output is because a Forced induction system can force more air into the combustion chamber than atmospheric pressure.

II. BOOSTING & DOWNSIZING

An engine is boosted to increase its output power and torque. Boosting isn't so straightforward to define, as there are various methods. An automotive engineer can look at modifying the air intake, the fuel injection system, the combustion process, or even the entire engine design to achieve the same thing. [8]

Downsizing simply means using a smaller displacement engine in favor of a larger engine. Doing this reduces internal losses (friction, thermal). Downsizing an engine alone would improve the engine fuel economy, however, it greatly degrades the transient response of a CI Engine. The proven limit for acceptable downsizing of diesel is 400cm3 per cylinder. Downsizing also reduces the quantity of CO2 the engine produces. An engine is often downsized by reducing the volume of the cylinders, or by reducing the quantity of cylinders, or by both. [3] [8]

A. Supercharging

The process of increasing the inlet air or charge density to increase the power output of the engine is called supercharging and the device used for increasing the pressure of the air above atmospheric pressure is called a supercharger.

The main object of supercharging is to increase the air charge per cycle and permit the burning of a larger amount of fuel and thus increase the power output of the engine. [4] [6]

It is preferred to fulfill the following requirements:

1) To overcome the effect of high altitudes
2) To reduce the weight of engine per Kw
3) To reduce the size of the engine to fit into limited space
4) To increase the power of an existing when the greater power demand occurs

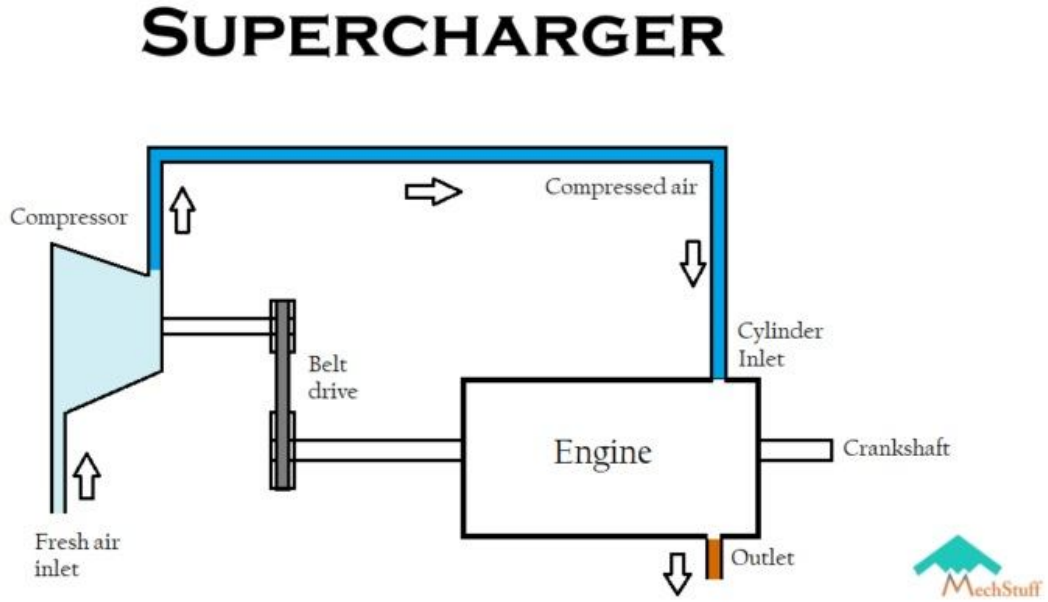

Fig. 1 Working of a Supercharger

B. Turbocharging

A turbocharger is a turbine-driven forced induction device that increases an internal combustion engine's efficiency and power output by forcing extra air into the combustion chamber and the process of forcing more air into the combustion chamber using a Turbocharger is known to be Turbocharging. [10]

The aim of a turbocharger is to improve an engine's volumetric efficiency by increasing the density of the intake gas (usually air) allowing more power per engine cycle. The turbocharger's compressor draws in ambient air and compresses it before it enters into the intake manifold at increased pressure. The purpose of a turbocharger is to increase the power output of an engine by supplying compressed air to the engine intake manifold so increased fuel can be utilized for combustion. The purpose of the altitude compensator is to maintain consistent power output and efficiency of an engine operating at all altitudes. [10]

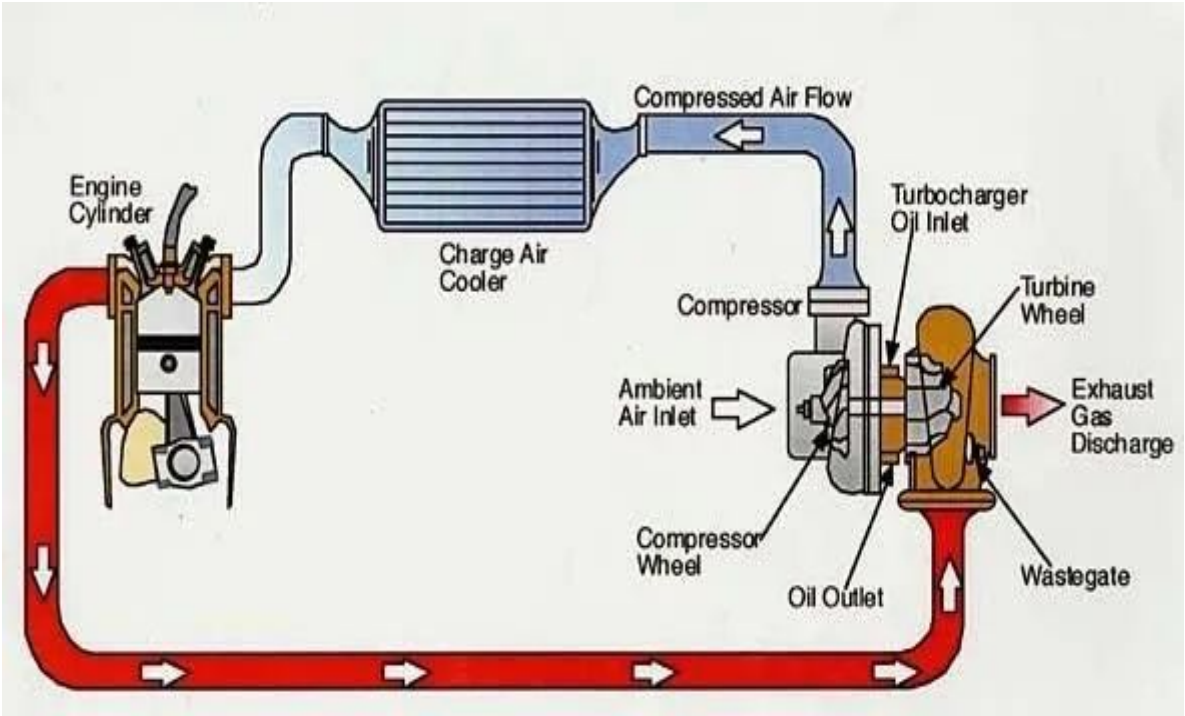

Fig. 1 Working of a Turbocharger

C. Other Methods for Improvement of Performance of an Engine:

1) Increasing speed of the engine,
2) Use of higher compression ratio,
3) Utilization of exhaust gas energy,
4) Use of two-stroke cycle.
5) Improving volumetric efficiency of the engine,
6) Increasing the charge density.

III.REVIEW OF LITERATURE

In 1987 the world's first two-stroke functional engine supercharger was made by Dugald Clerk. Gottlieb Daimler received a German patent for supercharging an internal combustion engine in 1885. Supercharger supplies high-density charge to the engine by compressing it through the compressor driven by the engine mechanically. The main problem with it is the loss of power used to drive the compressor from the engine output shaft. This loss can be up to 15% of engine output. Technology became popular by the name of Turbocharging in the early 1980s by eliminating loss of power, compressor was driven by a turbine utilizing the energy of exhaust gases of the engine by passing them through the turbine blades. From that day, various new technologies are introduced in turbocharging to improve its efficiency, and this improvement was carried out as follows:

Arvind Kumar [1] Demand for more & more power & extract the best efficiency from engines in the automobile industry is increasing at a rapid pace, engineers & companies are competing with each other to develop new technologies to ensure they have the most technologically advanced technology in the industry such that to attract potential customers. Many technologies over the years have been tested on automobiles such as fuel-saving technologies, direct injection systems, cylinder deactivation, variable valve timing, etc. but the most successful & most widely used technologies have been Superchargers & Turbochargers.

Looking at the difference between the two, the supercharger takes power from the crankshaft while the turbocharger takes power from the combustion gases. Superchargers are going to spin up to 50,000 RPM with speeds. The turbocharger is not connected to the engine and is able to spin much more quickly. Both are going to produce large amounts of power. There is no wastegate for a supercharger, which means smog is emitted from a supercharger. On the other hand, turbochargers have smog-changing equipment to reduce discharge carbon emissions. Turbochargers are going to run very hotly and have to be well insulated. Based on the vehicle itself will differ on which is best to determine. The explanation of why turbochargers are most widely used in Europe is due to small engines and regular four cylinders. At lower RPMs, superchargers will produce their boost than a turbocharger, while at high engine speeds, the turbocharger works best. Turbochargers are louder and superchargers are more reliable. It is easier to maintain superchargers than the complex turbocharger. The claims can go forward and back. It would be perfect if a supercharger were in the car so that the boost could occur at low RPMs, while at a higher rotation a turbocharger would put considerable power.

Determining which is better depends on the car itself being made. By the way, in price, both are about the same, so money is not a problem. With a supercharger, a regular car would do better. These are easier to install, and it's not as hard to tune up. In more specialized markets, the Turbocharger has its real niche. Overall, it is regarded as more efficient than a supercharger. From that point on, the consumer has to decide personally what type of car to own by installing the correct forced induction system to add more power to the drive.

Mohd Muqeem et. al., [2] concluded that without increasing the cylinder capacity Turbochargers enhance the output of an internal combustion engine. The application of such a mechanical device enables automotive manufacturers to adopt smaller displacement engines, commonly known as engine downsizing. Turbochargers were used to increase the potential of an earlier powerful IC engine, e.g. those used in motorsport. The importance of today is to provide a comfortable engineering solution to manufacturing economics and "greener" road vehicles. Due to these reasons, turbochargers are now becoming the most popular in automotive industry applications.

Sk. Abdul Azeez et. al., [5] stated that the main aim of the supercharger is fully satisfied and achieved the twin goals of the designer is of improving the power output of the engines and minimizing the exhaust emissions for eco-friendly without changing the engine design by simply assembling this supercharging. Now a day's every automobile sector company is designing engines to deliver fewer pollutants as per the followed standard norms specified by the government to their respective countries to decrease global warming. And also ultimately increasing the engine efficiency.

Due to the rich air-fuel mixture combustion emission will increase hence by turbo-charging the engine more power can be obtained with low emission.

The environmental atmospheric density reduces with the increased altitude. However, boost pressure recovery cannot make sure the power recovery of diesel engines due to the changing overall system efficiency and pumping process. The principle aim of the designer is to improved power output by minimizing the exhaust emissions like CO, CO2, NOx, etc.., the power output of a naturally aspirated engine depends on the amount of air inducted into the engine cylinder, the extent of utilization of the inducted air, the speed of the engine, the quantity of the fuel admitted and its combustion characteristics, thermal efficiencies of the engine. Supercharger may also be called as forced induction to increase the power output of the engine. It is a pressure boosting device that supplies air or mixture at a higher pressure to the engine cylinder is mostly applicable for modern applications like racing cars, marine and automotive engines where weight and spaces are important.

Prashant.N.Pakale et. al., [6] concluded that the power outputs of an engine increase with the increase in the amount of air or mixture in the cylinder, and the supercharger plays an important role in increasing the amount of air. Turbochargers are used throughout the automotive industry as they can enhance the output of the internal combustion (IC) engine without the need to increase its cylinder capacity.

The emphasis today is to provide a feasible engineering solution to manufacturing economics and "Greener" road vehicles. It is because of these reasons that superchargers and turbochargers are now becoming more and more popular in automobile applications. The aim of this paper is to provide a review of the techniques used in supercharging and turbocharging to increase the engine output and reduce exhaust emission levels.

Prakash Kumar Sen et. al., [7] studied the performance of supercharging process on the SI & CI engine and the application of supercharger to determine whether the mechanical action of a high-speed supercharger improves the engine performance. Most passenger automobiles are overpowered and probably 80 percent of such vehicles operate at less than 55 kmph for 90 percent of the time. Passenger car requires from 12 to 15 hp, but the engine carried is capable of developing from 50 to 55 hp. The result is that the car is operated for the greater part of the time at one-third to one-quarter throttle opening. Full power is needed only for accelerating and hill-climbing during the remainder of the time the excess weight of the engine and other parts must be carried at a loss of efficiency. That smaller engine can be used advantageously when equipped with a supercharger, the supercharger is used only when excess power is required.

Zhibin Wang et. al., [9] stated that the diesel engine supercharger technology is used most commonly. Turbocharger system can effectively improve power and torque of diesel engine, but turbo hysteresis exists. A mechanical supercharging system can boost at low speed, but the efficiency is lower. An electric supercharger can effectively improve the intake air at an early stage of accelerated working conditions, however, an electric supercharger will consume the engine power.

Mayur Ingale et. al., [10] Turbochargers multiply the output of the internal combustion (IC) engine without the need to increase its cylinder capacity all over the automotive industries. The application of such a mechanical device enables automotive manufacturers to adopt greater power and high torque applications. There are many inventions done to enhance the performance of IC engines. So most engines nowadays are employed with turbochargers and superchargers. It is known that the power outputs of an engine increases with the increase in the amount of air or mixture in the cylinder and the supercharger plays an important role in increasing the amount of air. It is because of these reasons that superchargers and turbochargers are now becoming more and more popular in automobile applications.

IV. CONCLUSIONS

In recent years various new advancements are being done for improving the power output of an engine and minimizing the exhaust emissions by making different changes and installing some additional accessories forced induction being one of them. From the analysis of experimental results in papers reviewed, the following can be summarized.

A. Forced Induction Technologies will give more power compared to the same size naturally aspirated engine.
B. Better Fuel Economy by the way of more power and torque from the same sized engine when Forced Induction is utilized.
C. Turbocharger will have Better thermal efficiency over the naturally aspirated engine and supercharged engine because the engine exhaust is being used to do the useful work which otherwise would have been wasted.
D. The high-altitude performance of a supercharged engine is significantly better. Because the reduced engine is smaller; it is, therefore, less noisy than a naturally aspirated engine with identical output and a Turbocharged Engine.
E. Turbocharger will tend to increase the Engine Weight whereas with Supercharger it's vice versa.

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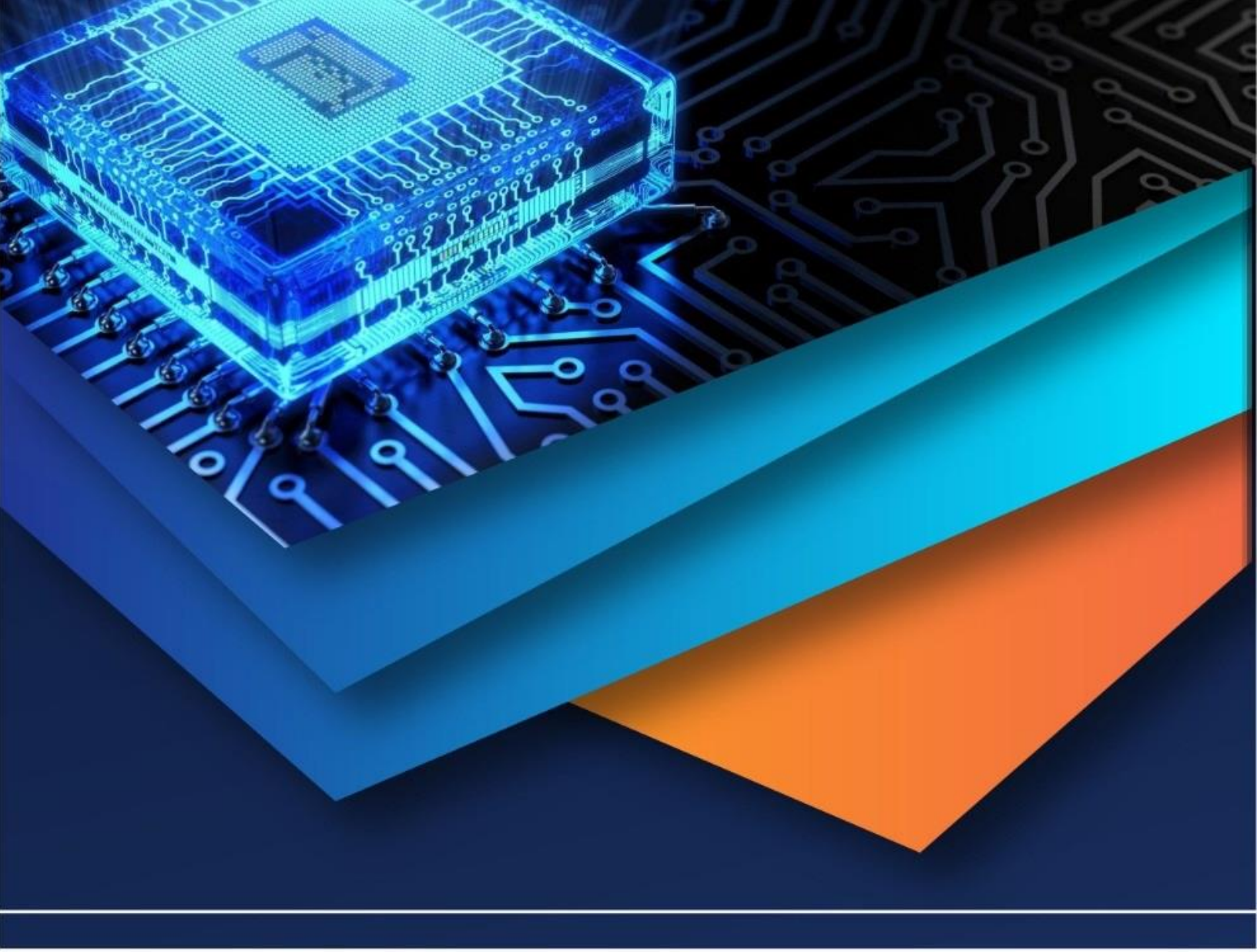

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