# Effects of Supercharger and Turbocharger on I.C Engine Performance – A Review

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*Abstract:* The aim of this paper is to study the different types of superchargers and turbo chargers in modern trends and those how far useful in now a days, as a demand of new efficient and eco friendly engines is incrementing new technologies are developing. 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 behavior of IC engine with application of turbo/super charger and need of turbo/super charger installation is studied by observing of its effects. 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 ect.., the power output of a naturally aspirated engine depends on amount of air inducted into the engine cylinder, extent of utilization of the inducted air, the speed of the engine, quantity of the fuel admitted and its combustion characteristics, thermal efficiencies of the engine. Supercharger may also Called as forced induction to increase the power output of the engine. It is a pressure boosting device which 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.

*Index Terms* - **Turbocharger, Supercharger, Exhaust gas recovery, Inter cooler, CO, NOx.**

## I. INTRODUCTION

**1.1 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.

### 1. 2. INTRODUCTION TO SUPERCHARGING

It is known fact that the power output of an engine increases with an increase in amount of air or mixture in the cylinder at the beginning of compression stroke because it allows the burning of more quantity of fuel. The amount of air induced per unit time can be increased by increasing engine speed or increasing air density during suction stroke. The increase in engine speed requires rigid and robust engine as the inertia load increases rapidly with an increases speed. The engine friction and bearing loads also increase and volumetric efficiency falls with increasing speed of engine. Therefore this is not possible. Now another method in which we have to increase the suction pressure is called supercharging. Equipment used for this is called Supercharger.

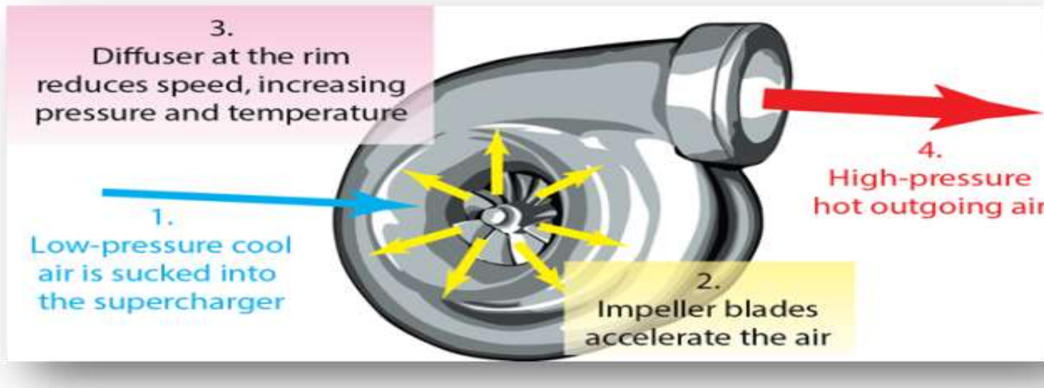


*Figure1.1: Principle of supercharger*

### 1.3. INTRODUCTION TO TURBOCHARGING

BMW was invented to use turbo-charging in a production passenger car when they launched the 2002 in 1973. The car was brilliantly packaged too and paved the way for a simply magnificent 'Turbo Era' in the automotive world. A turbocharger is a device used to allow more power to be produced for an engine of a given size. A turbocharged engine can be more powerful and efficient than a naturally aspirated engine because the turbine forces more intake air, proportionately more fuel, into the combustion chamber than if atmospheric pressure alone is used. Its purpose is to increase the volumetric efficiency of the combustion chamber. Various new technologies have been introduced to assist the turbo-charging of internal combustion engine so that the volumetric efficiency may improve more. These technologies include inter-cooling of the charged air before going in to the combustion chamber so that its mass flow rate is increased. The other technology is twin charging in which firstly the engine is boosted by a supercharger then it is boosted by a turbocharger when the energy of exhaust gas is sufficient to rotate the turbine blades. In turbo-charging, the turbocharger is being driven by a gas turbine using the energy in exhaust gases. The major parts of turbocharger are turbine wheel, turbine housing, turbo shaft, comp. wheel, comp. housing & bearing housing. The volumetric efficiencies of supercharging and turbo-charged engines are having more than the 100% as compared to naturally aspirated engines.

## 2. RESULT AND DISCUSSION

### 2.1 Objective of Supercharging

Supercharging is a process which helps to increase the suction pressure of I.C. Engines above the atm. pressure. 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.

It is preferred to fulfill the following requirements:

1. To overcome effect of high attitudes
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.

### 2.1.1 Working of Supercharging

The power of an aircraft engine depends on the pressure developed in its individual cylinders whilst on their working strokes. This pressure arises from the combustion of liquid fuel which has been introduced into the cylinder along with a charge of air during the induction stroke. Since it is a chemical fact that good combustion is possible only over a comparatively narrow range of mixture strengths, it follows that the amount of fuel that can be burnt per power stroke is limited by the weight of air in the cylinder. More air means more power and so the current demand for increased engine outputs is met by larger cylinders, by more of them, or by running at higher speeds To deal with a greater weight of air in unit time. With a normal (un-supercharged) engine, it is the pressure of the atmosphere which forces air through the carburetor and into the cylinders on the induction stroke. As atmospheric pressure falls with altitude, the weight of air available for combustion also falls off and power goes lower in sympathy. It was soon realized that this natural fall-off with altitude could be avoided if we could deceive the engine that it was still at sea level by blowing air into its induction system using some kind of pump. This process is "supercharging."Keeping the air that enters the engine cool is an important part of the design of both superchargers and turbochargers. Compressing Air increases its temperature, so it is common to use a small radiator called an intercooler between the pump and the engine to reduce the temperature of the air. There are three main categories of superchargers for automotive use: Centrifugal turbochargers – driven from exhaust gases. Centrifugal superchargers – driven directly by the engine via a belt-drive. Positive displacement pumps – such as the Roots, Twin Screw (Lysholm) and vane type. Centrifugal compressors, sometimes termed radial compressors, are a sub-class of dynamic axi-symmetric work-absorbing turbo machinery. The idealized compressive dynamic turbo-machine achieves a pressure rise by adding kinetic energy/velocity to a continuous flow of fluid through the rotor or impeller. This kinetic energy is then converted to an increase in potential energy/static pressure by slowing the flow through a diffuser. The pressure rise in impeller is in most cases almost equal to the rise in the diffuser section. These centrifugal compressors are well utilized for better efficiencies up to 85 to 90 %. The usages of different compressors in different methods are as following figures.

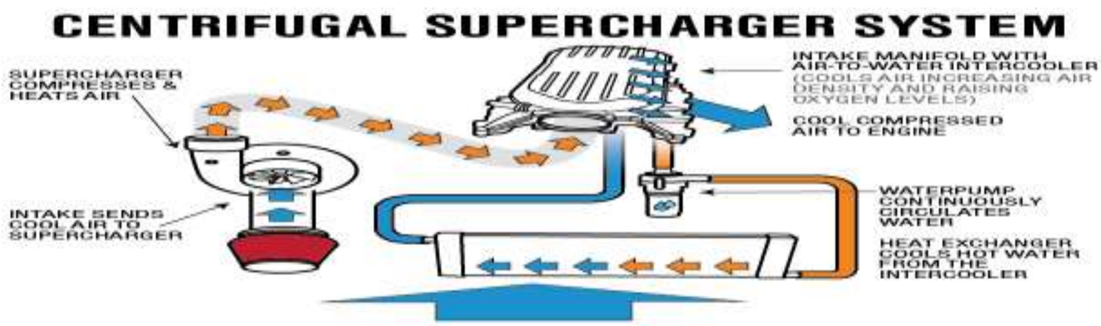


*Figure1.2: Centrifugal turbochargers – driven from exhaust Gases*

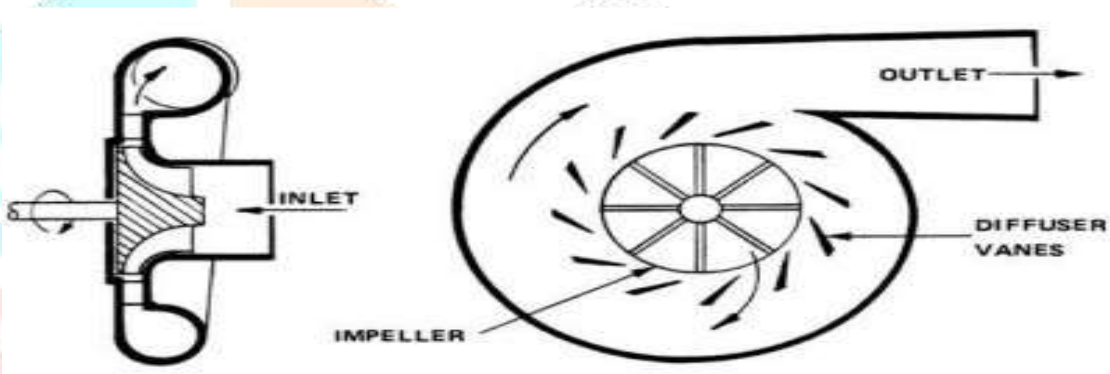


*Figure 1.3: Centrifugal supercharger overview*

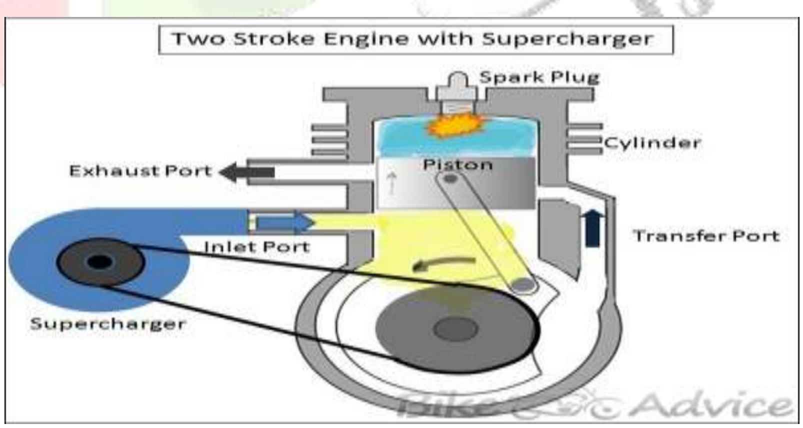


*Figure1.4: Centrifugal superchargers – driven directly by the engine via a belt-drive*

A supercharger is an air compressor that increases the pressure or density of air supplied to an internal combustion engine. This gives each intake cycle of the engine more oxygen, letting it burn more fuel and do more work, thus increasing power. Power for the supercharger can be provided mechanically by means of a belt, gear, shaft, or chain connected to the engine's crankshaft. When power is provided by a turbine powered by exhaust gas, a supercharger is known as a *turbo supercharger*– typically referred to simply as a *turbocharger* or just *turbo*. Common usage restricts the term *supercharger* to mechanically driven units.

These are 40 to 50 % efficient in usage

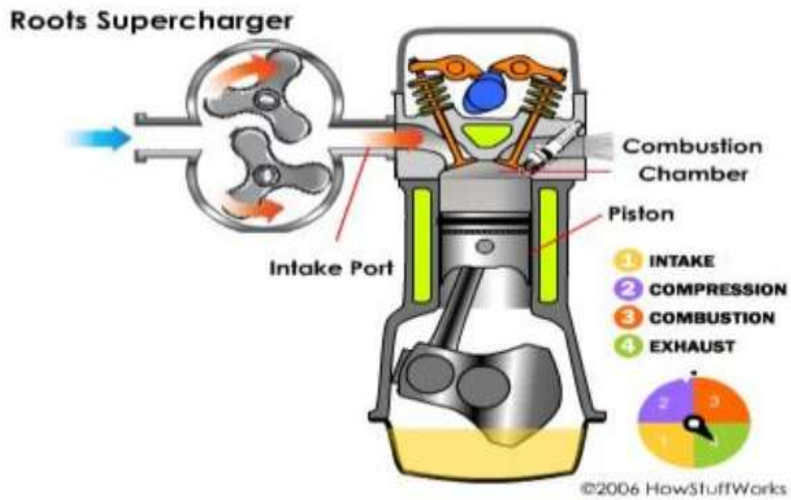


*Figure 1.5: Roots blower type of supercharger*

A **rotary-screw compressor** is a type of gas compressor that uses a rotary-type positive-displacement mechanism. They are commonly used to replace piston compressors where large volumes of high-pressure air are needed, either for large industrial applications or to operate high-power air tools such as jack hammers. The gas compression process of a rotary screw is a continuous sweeping motion, so there is very little pulsation or surging of flow, as occurs with piston compressors.

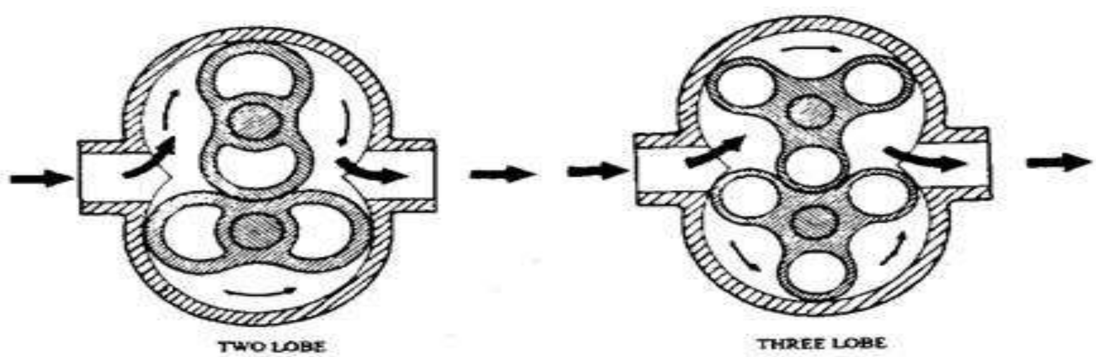


*Figure1.6: Overview of Screw type or Lysholm compressor*

The positive displacement principle applies in these pumps:

- Rotary lobe pump
- Progressive cavity pump
- Rotary gear pump
- Piston pump
- Diaphragm pump
- Screw pump
- Gear pump
- Hydraulic pump
- Rotary vane pump
- Peristaltic pump
- Rope pump
- Flexible impeller pump

In a naturally aspirated engine, air for combustion (diesel cycle in a diesel engine, or specific types of Otto cycle in gasoline engines – namely gasoline direct injection), or an air/fuel mixture (traditional Otto cycle petrol engines) is drawn into the engines cylinders by atmospheric pressure acting against a partial vacuum that occurs as the piston travels downwards toward bottom dead centre during the intake stroke. Owing to innate restriction in the engine's inlet tract which includes the intake manifold, a small pressure drop occurs as air is drawn in, resulting in a volumetric efficiency of less than 100 percent – and a less than complete air charge in the cylinder. The density of the air charge, and therefore the engine's maximum theoretical power output, in addition to being influenced by induction system restriction, is also affected by engine speed and atmospheric pressure, the latter which decreases as the operating altitude increases. This is in contrast to a forced induction engine, in which a mechanically driven supercharger or an exhaust-driven turbocharger is employed to facilitate in increasing the mass of intake air beyond what could be produced by atmospheric pressure alone. As a two-stroke diesel engine is incapable of natural aspiration as defined above, some method of charging the cylinders with scavenging air must be integrated into the engine design. This is usually achieved with a positive displacement blower driven by the crankshaft. The blower does not act as a supercharger in this application, as it is sized to produce a volume of air flow that is in direct proportion to engine's requirement for combustion, at a given power and speed. By the Society of Automotive Engineer's definition, a mechanically scavenged two-stroke diesel engine is considered to be naturally aspirated. Most automobile petrol engines, as well as many small engines used for non-automotive purposes, are naturally aspirated. Most modern diesel engines powering highway vehicles are turbocharged to produce a more favorable power-to-weight ratio, as well as better fuel efficiency and lower exhaust emissions. Turbo-charging is nearly universal on diesel engines that are used in railroad, marine engines, and commercial stationary applications (electrical power generation, for example). Forced induction is also used with reciprocating aircraft engines to negate some of the power loss that occurs as the aircraft climbs to higher altitudes

**Advantages**

- Easier maintenance
- Lower production and development costs
- Higher reliability (less separate parts)
- Direct throttle response (no turbo lag)

**Disadvantages**

- Lower efficiency
- Lower power-to-weight ratio
- Small potential for tuning
- Greater power loss at higher elevation (lower air pressure) compared to forced induction counterparts

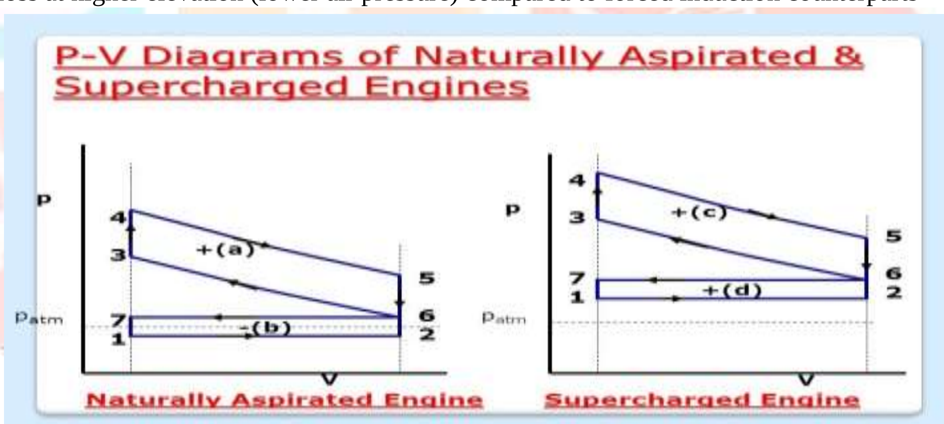


*Figure 1.7: P-V diagram of both naturally aspirated and supercharged engines*

**2.1.2 Benefits of Supercharging**

- Due to the lower volumetric displacement of the supercharged engine, frictional & thermal losses are less.
- Brake power will increase about 30-45 percent because of increase in supercharged pressure as more amount of fuel will be burnt within the same period as the mass taken per stroke is increased.
- The power-to-weight ratio, i.e. kilowatt (power output)/kilograms (engine weight); of the Supercharged engine is much better than that of the naturally aspirated engine.
- The supercharged engine’s installation space requirement is smaller than that of a naturally aspirate engine with the same power output.
- The high altitude performance of a supercharged engine is significantly better. Because of reduced engine is smaller; it is therefore less noisy than a naturally aspirated engine with identical output.
- It is very simple for high speed engine.

**2.1.3 Limitations of Supercharging**

- The biggest disadvantage of superchargers is also their defining characteristic: Because the crankshaft drives them, they must steal some of the engine's horsepower. A supercharger can consume as much as 20 percent of an engine's total power output.

- Not able to guarantee maximum performance of the supercharger due to physical limitations of the system.
- Reliability of engine decreases with increase in maximum pressure in the cylinder
- Increase in pressure increases thermal load on engine due to increase in the rate of heat release.

### 2.1.4 Effects of Supercharging

- Higher power output
- Grater induction of charge mass
- Better atomization of fuel
- Better mixing of fuel and air
- Better scavenging of products (exhaust gases)
- Better torque characteristics over the whole speed range
- Quicker acceleration of vehicle
- More complete and smooth combustion
- Inferior and poor ignition quality fuel to be usage
- Increased detonation tendency in S.I engines
- Improved cold starting
- Reduced exhaust smoke
- Reduced specific fuel consumption
- Increased mechanical efficiency
- Increased thermal efficiency

### 2.2.1 Working of Turbocharger

Since the power a piston engine can produce is directly dependent upon the mass of air it can ingest, the purpose of forced induction (turbo-supercharging and super charging) is to increase the inlet manifold pressure and density so as to make the cylinders ingest a greater mass of air during each intake stroke. A supercharger is an air compressor driven directly by the engine crankshaft, and as such, consumes some of the power produced by the combustion of fuel, thereby increasing BSFC and engine wear for a given amount of produced power. A turbocharger consists of a single-stage radial-flow (centrifugal‖) compressor (air pump), which is driven by a single-stage radial-flow turbine, instead of being driven directly by the crankshaft. The turbine extracts wasted kinetic and thermal energy from the high-temperature exhaust gas flow and produces the power to drive the compressor, at the cost of a slight increase in pumping losses.

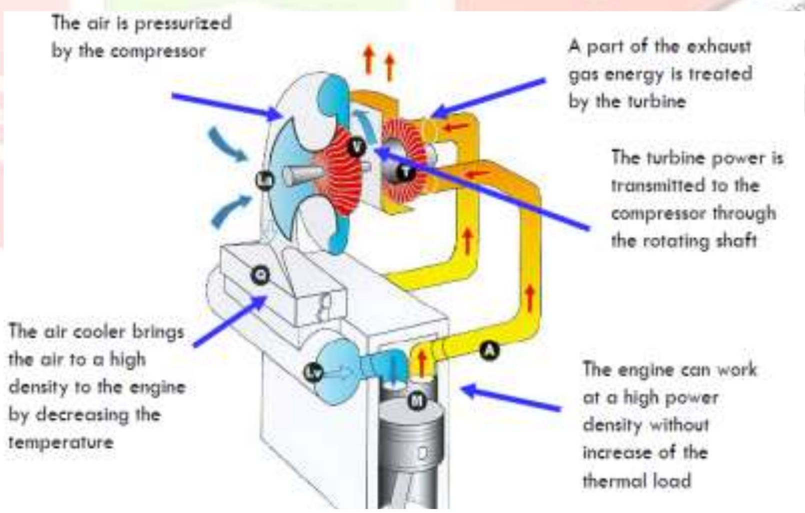


*Figure 1.8: Working of Turbocharger*

### 2.2.2 Two-Stage Turbo-charging for Four-Stroke Engine

The first four-stroke engines with two-stage turbo-charging are on the market. At ABB, two-stage turbo-charging is already entering its second generation. On diesel engines the aim is to further enhance NOx emissions, fuel consumption and power density and on gas engines power density, load acceptance and operating flexibility. Ease-of-maintenance is also a high priority.

### 2.2.3 Two-Stage Turbo-charging Benefits

The first generation of ABB Turbo Systems' Power two-stage turbo-charging concept has been successfully applied on large four-stroke engines since 2010 [1, 2, 3]. Engine efficiency gains and emissions reduction have been demonstrated which are clearly beyond the potential of single-stage turbo-charging. ABB Turbo Systems has now developed the second generation of its Power systems for large four- stroke engines, to fully realize the potentials offered by the presence of two turbo-charging stages. A key driver is enabling extreme Miller Cycles on large four-stroke engines. On diesel engines, the Miller Cycle and high pressure turbo-charging – in particular two-stage turbo-charging – enable substantial reductions in emissions of oxides of nitrogen (NOx) while improving fuel efficiency and power density. Alternatively, highly fuel optimized designs are possible when an SCR catalyst (Selective Catalytic Reduction) is applied for subsequent treatment of the exhaust gases to reduce NOx emissions down to the required levels. The Miller Cycle in combination with high pressure turbo-charging is also applicable on gas engines, where the reduction in cylinder charge temperature can be used to reduce the tendency for combustion knock and thus allow higher compression ratios/efficiencies. Key performance improvements are added to the intrinsically low NOx emissions of lean burn gas engines burning zero sulphur fuels while benefitting from actual and predicted low fuel prices. Improved engine efficiency, enhanced power density and reduced power loss at high altitude and in hot and humid ambient conditions result.

### 2.2.4 Benefits of Turbo-charging

- More power compared to the same size naturally aspirated engine.
- Better thermal efficiency over naturally aspirated engine and super charged engine, because the engine exhaust is being used to do the useful work which otherwise would have been wasted.
- Better Fuel Economy by the way of more power and torque from the same sized engine. A century of development and refinement—for the last century the SI engine has been developed and used widely in automobiles.
- Low cost–The SI engine is the lowest cost engine because of the huge volume currently produced.
- High Thermal efficiency.
- Better volumetric efficiency.
- Continual development of this technology has produced an engine that easily meets emissions and fuel economy standards. With current computer controls and reformulated gasoline, today's engines are much more efficient and less polluting than those built 20 years ago.
- High speed obtained.
- Better average obtained.
- Eco-friendly.

### 2.2.5 Limitations of Turbo-charging

1) Engine weight will increase.
2) If there will be improper maintenance then there will be problem in turbo such as turbo lag.
3) Engine cost will increase.

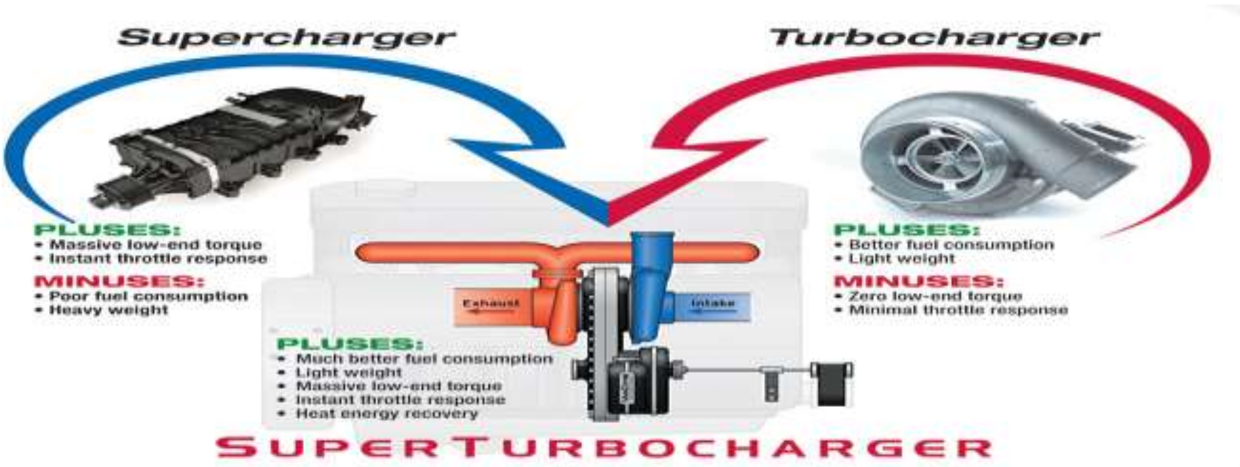


*Figure 1.9: Final aspects of super-turbocharger diagram*

## 3. CONCLUSION

In this paper the main aim of the super charger 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 companies are designing the engines to deliver less 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

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