Product Knowledge Document

Turbocharger

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INTRODUCTION

A turbocharger, also known as a turbo, is a turbine-driven forced induction device that increases an internal combustion (IC) engine's efficiency and power output by forcing extra compressed air into the combustion chamber.

Turbochargers are commonly used on truck, car, train, aircraft, and construction equipment engines. They are most often used with Otto cycle and Diesel cycle internal combustion engines.

INTRODUCTION

Turbochargers were originally known as turbosuperchargers when all forced induction devices were classified as superchargers. The key difference between a turbocharger and a conventional supercharger is that a supercharger is mechanically driven by the engine, often through a belt connected to the crankshaft, whereas a turbocharger is powered by a turbine driven by the engine's exhaust gas.

When compared with a mechanically driven supercharger, turbochargers tend to be more efficient, but less responsive. Twin charger refers to an engine with both a supercharger and a turbocharger.

A turbocharger also used to increase fuel efficiency without increasing power. This is achieved by diverting exhaust waste energy, from the combustion process, and feeding it back into the turbo's "hot" intake side that spins the turbine.

INDIAN STANDARDS FOR INTERNAL COMBUSTION ENGINES OF THE PRESSURE CHARGED TYPES WITH OR WITHOUT AFTER COOLER

There is standard available to be followed by the Indian manufacturers to meet testing requirements of internal combustion engines of the pressure charged types with or without after cooler.

The below mentioned is the Standard –

1. IS 13018 : 1990 – Internal combustion engines – methods of test for pressure charged engines.

In the preparation of above Indian Standard considerable assistance is derived from the following International standards:

1. **IS0 3046 (Part 1) : 1986-** Reciprocating internal combustion engines - Performance : Part 1 Standard reference conditions and declarations of power, fuel consumption and lubricating oil consumption
2. **IS0 3046 (Part 2) : 1977-** Reciprocating internal combustion engines -- Performance : Part 2 Test methods
3. **IS0 3046 (Part 3) : 1979-** Reciprocating internal combustion engines - Performance : Part 3 Test measurements For the purpose of deciding whether

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HISTORY

1. The turbocharger was invented by Swiss engineer Alfred Buchi (1879–1959), the head of diesel engine research at Gebruder Sulzer (now simply called Sulzer), engine manufacturing company in Winterthur.

2. The first use of Turbocharging technology based on his design was for large marine engines, when the Germen Ministry of transport commissioned the construction of the "Preussen" and "Hansestadt Danzig" passenger liners in 1923.

3. In 1918,General Electric engineer Sanford Alexander Moss attached a turbocharger to a V12 Liberty aircraft engine. The engine was tested at Pikes Peak in Colorado at 14,000 ft (4,300 m) to demonstrate that it could eliminate the power loss usually experienced in internal combustion engines.

4. Turbochargers were first used in production aircraft engines such as theNapier Lioness in the 1920s.

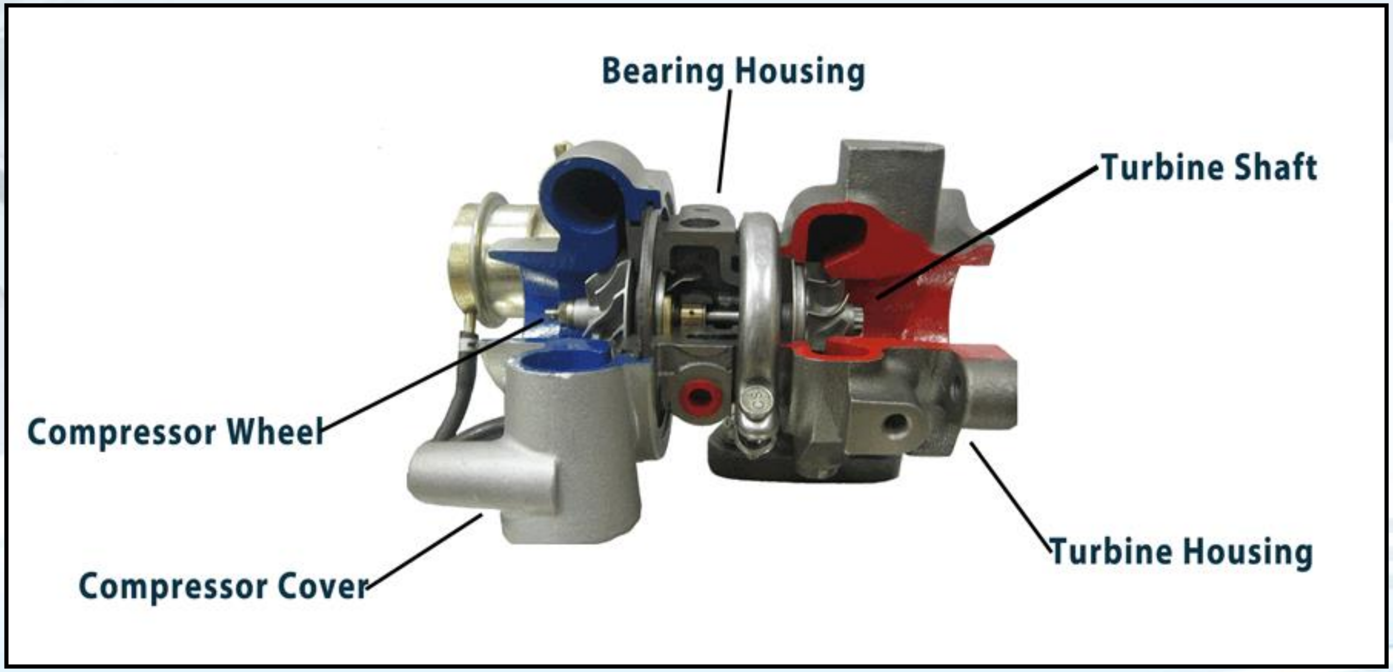
5. Now, Turbochargers are widely used in car and commercial vehicles because they allow smaller-capacity engines to have improved fuel economy, reduced emissions, higher power and considerably higher torque.

TURBOCHARGERS - CONSTRUCTION

COMNPONENTS

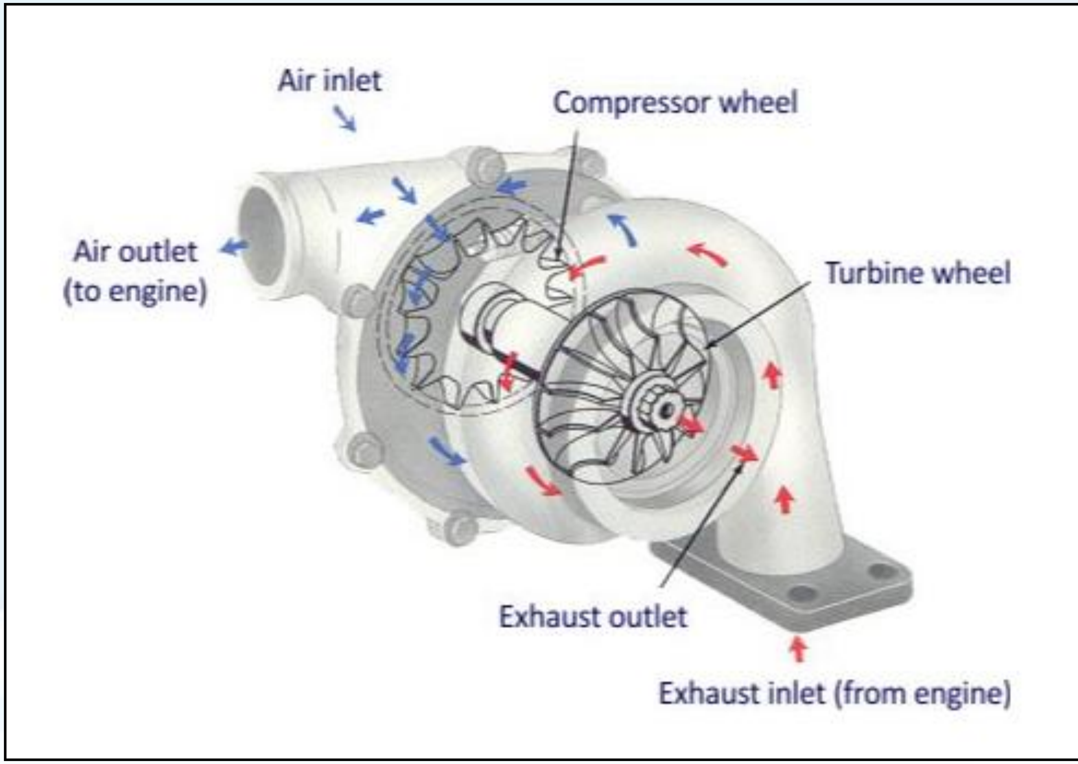
The turbocharger has three main components:

1. **The turbine**, which is always a radial inflow turbine (but is always a single-stage axial inflow turbine in large Diesel engines)
2. **The compressor**, which is almost always a centrifugal compressor.
3. **The center housing/hub rotating assembly**



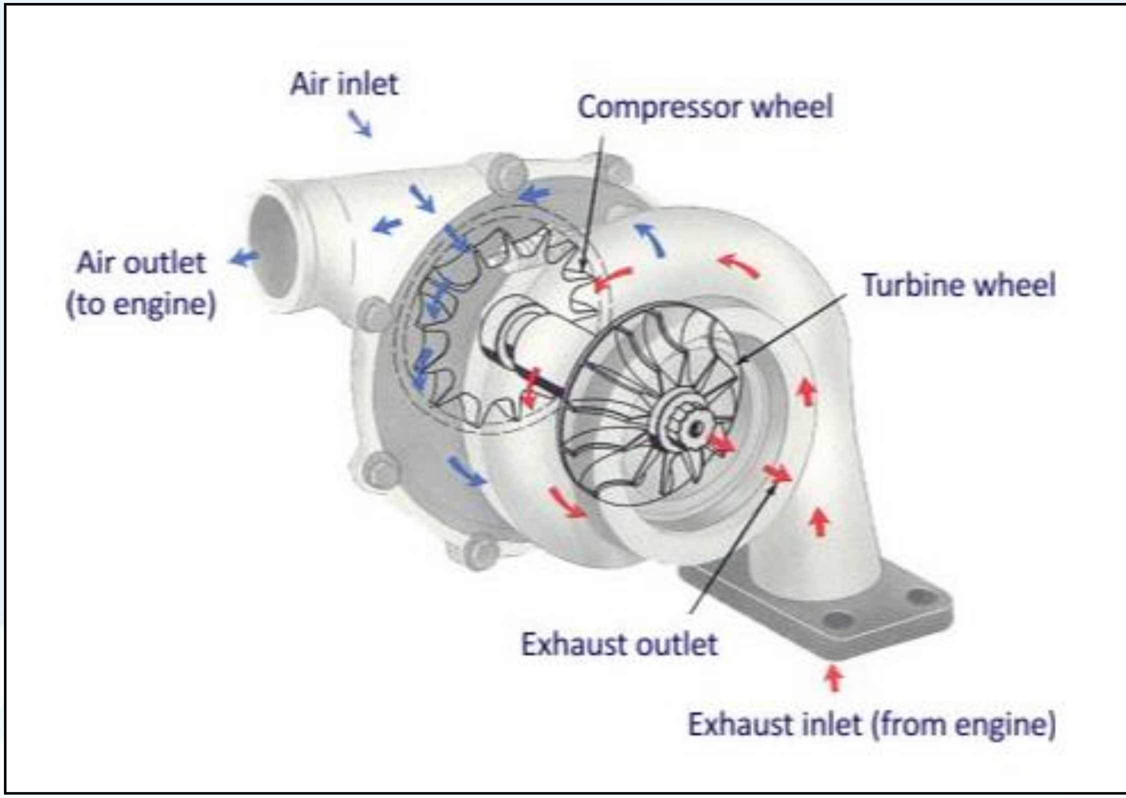
1. Turbocharger Turbine

- The turbocharger turbine, which consists of a turbine wheel and a turbine housing, converts the engine exhaust gas into mechanical energy to drive the compressor. The gas, which is restricted by the turbine's flow cross-sectional area, results in a pressure and temperature drop between the inlet and outlet. This pressure drop is converted by the turbine into kinetic energy to drive the turbine wheel.
- There are two main turbine types: axial and radial flow. In the axial-flow type, flow through the wheel is only in the axial direction. In radial-flow turbines, gas inflow is centripetal, i.e. in a radial direction from the outside in, and gas outflow in an axial direction.



2. Turbocharger Compressors

- Turbocharger compressors are generally centrifugal compressors consisting of three essential components: compressor wheel, diffuser, and housing. With the rotational speed of the wheel, air is drawn in axially, accelerated to high velocity and then expelled in a radial direction.
- The diffuser slows down the high-velocity air, largely without losses, so that both pressure and temperature rise. The diffuser is formed by the compressor back plate and a part of the volute housing, which in its turn collects the air and slows it down further before it reaches the compressor exit



3. Center housing/hub rotating assembly

- The turbine-compressor common shaft is supported by a bearing system in the center housing (bearing housing) located between the compressor and turbine. The shaft wheel assembly refers to the shaft with the compressor and turbine wheels attached, i.e., the rotating assembly.

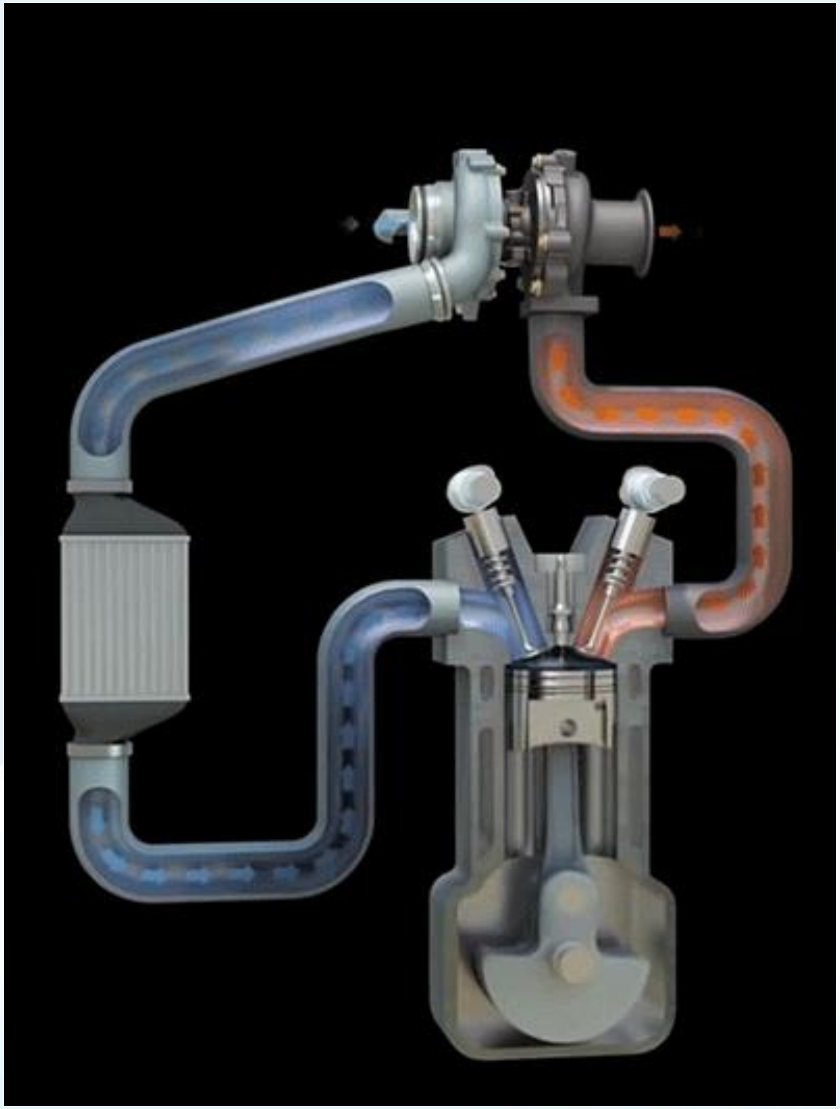
- The center housing is commonly cast from grey cast iron but aluminium can also be used in some applications. Seals help keep oil from passing through to the compressor and turbine. Turbochargers for high exhaust gas temperature applications, such a spark ignition engines, can also incorporate cooling passages in the center housing.

- **Bearing-** important ones include: the control of radial and axial motion of the shaft and wheels and the minimization of friction losses in the bearing system.

- **Seals-** Seals are located at both ends of the bearing housing. These seals represent a difficult design problem due to the need to keep frictional losses low, the relatively large movements of the shaft due to bearing clearance and adverse pressure gradients under some conditions.

TURBOCHARGERS - WORKING

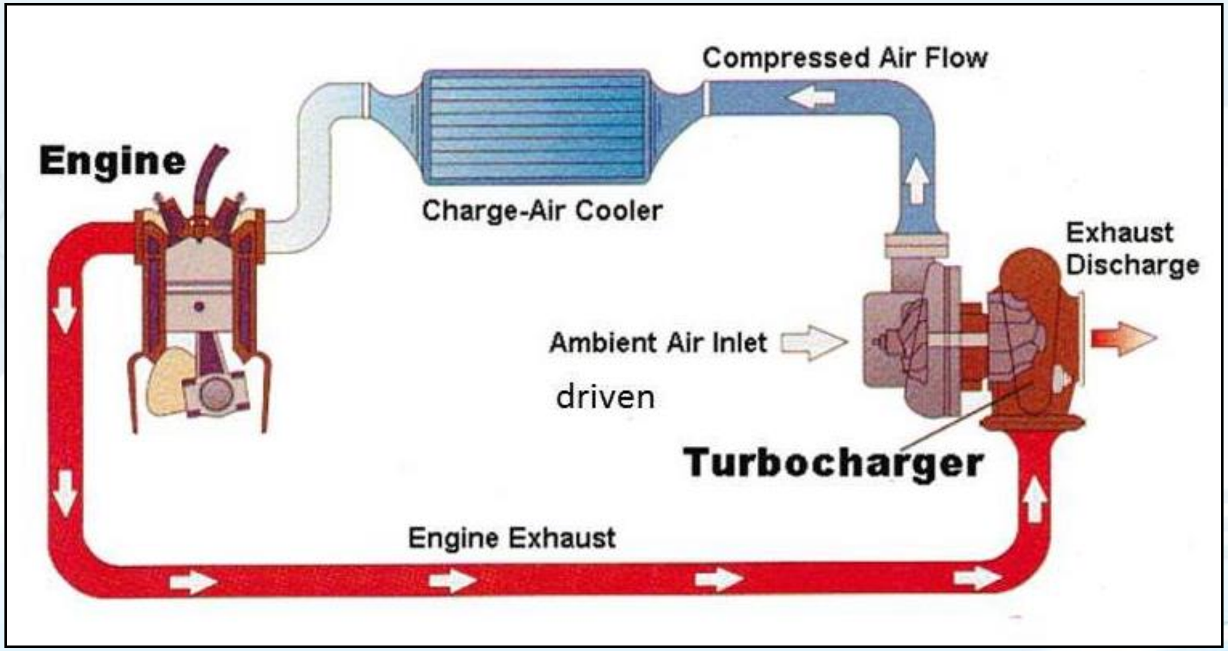
Working principle– Turbochargers



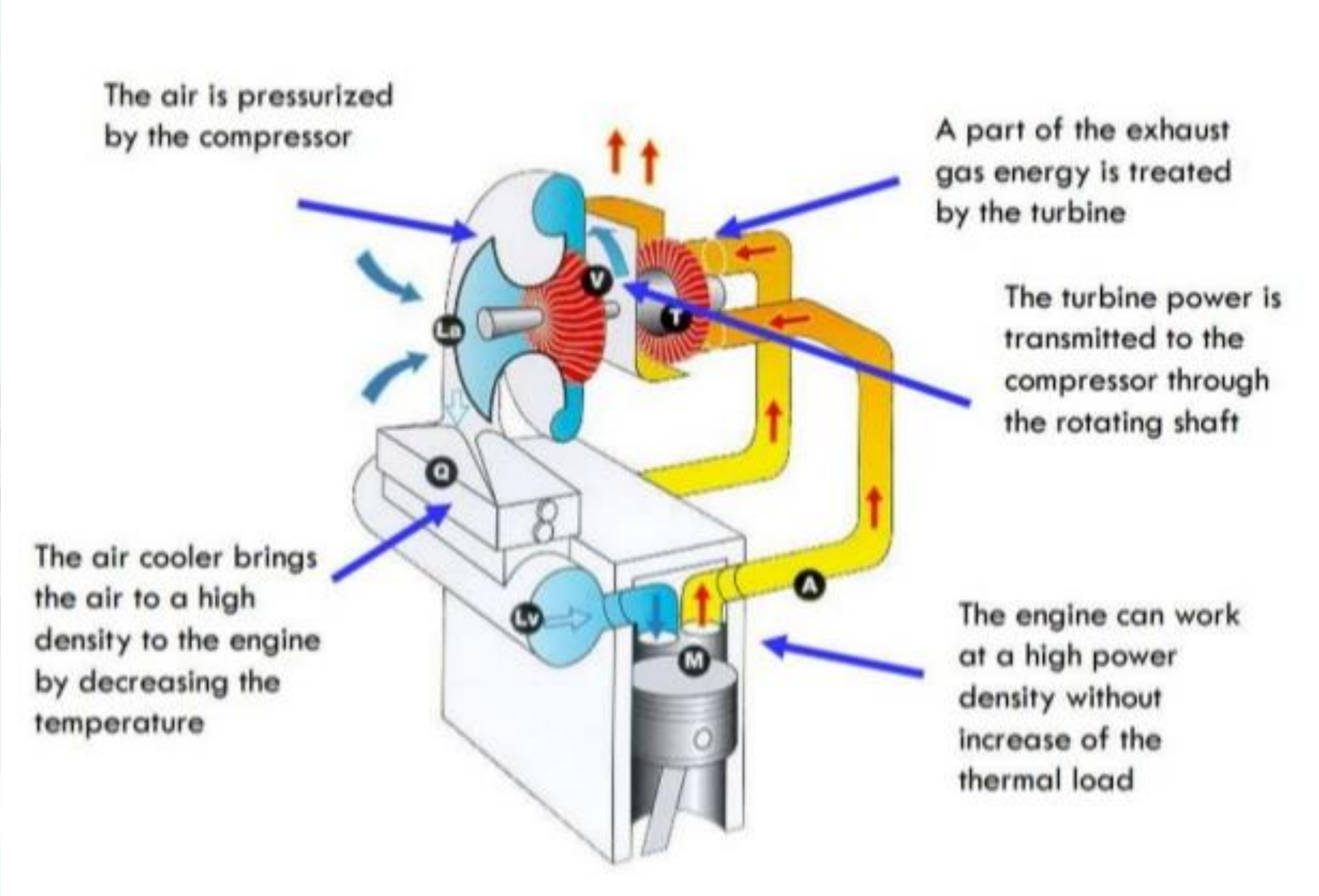
Working principle– Turbochargers

A turbocharger consists of a compressor wheel and exhaust gas turbine wheel coupled together by a solid shaft and that is used to boost the intake air pressure of an internal combustion engine.

The exhaust gas turbine extracts energy from the exhaust gas and uses it to drive the compressor and overcome friction. In most automotive-type applications, both the compressor and turbine wheel are of the radial flow type. Some applications, such as medium- and low- speed diesel engines, can use an axial flow turbine wheel instead of a radial flow turbine.



Working principle– Turbochargers



Working principle– Turbochargers

The objective of a turbocharger is to improve an engine's volumetric efficiency by increasing. The turbocharger's compressor draws in ambient air and compresses it before it enters into the intake manifold at increased pressure. Density of the intake gas (usually air) allowing more power per engine cycle. This results in a greater mass of air entering the cylinders on each intake stroke. The power needed to spin the centrifugal compressor is derived from the kinetic energy of the engine's exhaust gases.

In petrol engine turbocharger applications, boost pressure is limited to keep the entire engine system inside its thermal and mechanical design operating range. Over-boosting an engine frequently causes damage to the engine in a variety of ways including pre-ignition, overheating, and over-stressing the engine's internal hardware. For example, Engine knocking (also known as detonation) and the related physical damage to the engine.. Opening the waste gate allows the excess energy destined for the turbine to bypass it and pass directly to the exhaust pipe, thus reducing boost pressure. The waste gate can be either controlled manually or by an actuator (in automotive applications, it is often controlled by the engine control unit.

Tire Classification of Turbocharger

Types of Turbochargers

1. Twin-turbo or bi-turbo
2. Twin-scroll or divided turbochargers
3. Variable-geometry or variable-nozzle turbochargers

1. Twin-turbo or bi-turbo

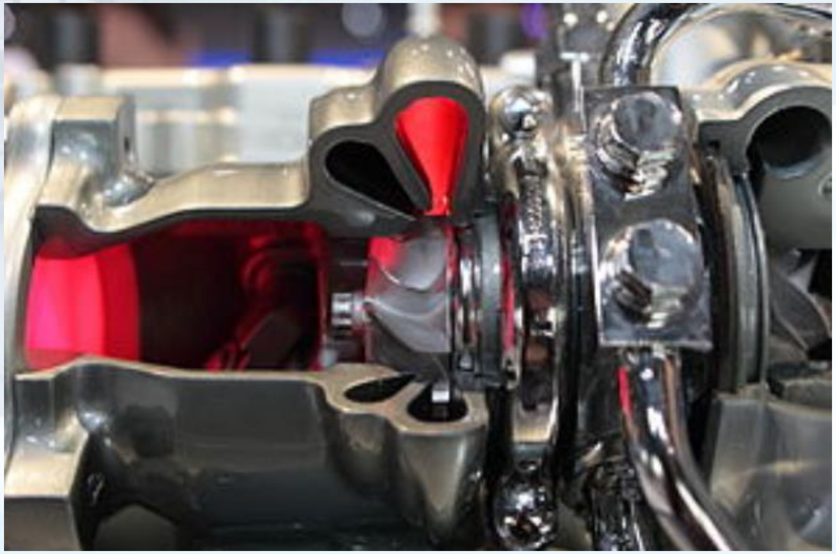
Twin-turbo or bi-turbo designs have two separate turbochargers operating in either a sequence or in parallel. Two-stage variable twin-turbos employ a small turbocharger at low speeds and a large one at higher speeds. They are connected in a series so that boost pressure from one turbocharger is multiplied by another.

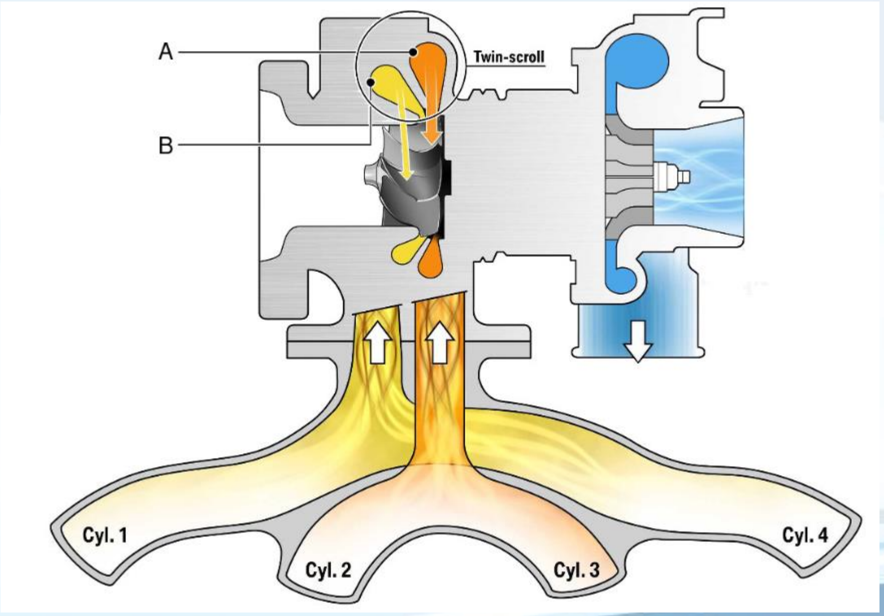
Smaller turbochargers have less turbo lag than larger ones, so often two small turbochargers are used instead of one large one. This configuration is popular in engines over 2,500 CCs and in V-shape or boxer engines

2. Twin-scroll or divided turbochargers

Twin-scroll or divided turbochargers have two exhaust gas inlets and two nozzles, a smaller sharper angled one for quick response and a larger less angled one for peak performance.

In twin-scroll designs, the exhaust manifold physically separates the channels for cylinders that can interfere with each other, so that the pulsating exhaust gasses flow through separate spirals





3. Variable-geometry or variable-nozzle turbochargers

The variable geometry turbine allows significant flexibility over the pressure ratio across the turbine. In diesel engines, this flexibility can be used for improving low speed torque characteristics, reducing turbocharger lag and driving EGR (exhaust gas recirculation) flow. The most common designs of variable geometry turbochargers include the pivoting vane design and the moving wall design.

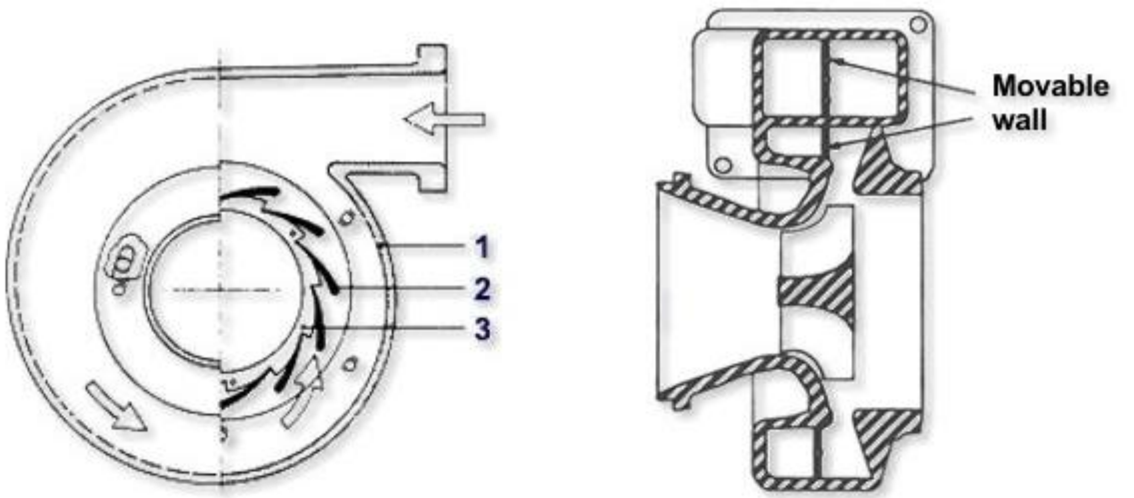


Figure . Pivoting vane (left) and moving wall (right) variable geometry turbochargers
1. Turbine housing; 2. Variable angle vanes; 3. Adjusting ring

3. Variable-geometry or variable-nozzle turbochargers

The benefits of variable geometry turbines over waste gated turbines include :-

- no throttling loss of the waste gate valve;
- higher air–fuel ratio and higher peak torque at low engine speeds;
- improved vehicle accelerations without the need to resort to turbines with high pumping loss at high engine speeds;
- potential for lower engine ΔP (the difference between exhaust manifold and intake manifold pressures);
- ability to provide engine braking;
- ability to raise exhaust temperature for after treatment system management.

Additional technologies used in turbocharger installations

Additional technologies used in turbocharger installations

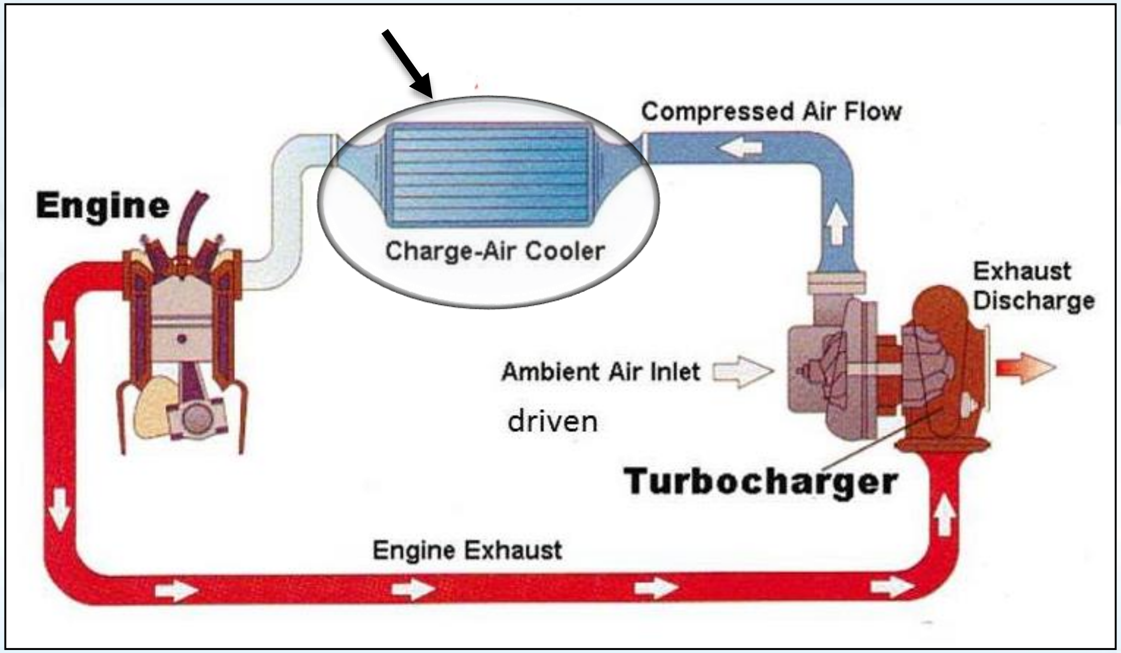
Following are some additional technologies commonly used in turbocharger installation-

1. Intercooling
    a. Top-mount (TMIC)
    b. Front-mount intercoolers (FMIC)
2. Water injection
3. Methanol Injection
4. Waste gate
5. Anti-surge/dump/blow off valves

Intercooling

When the pressure of the engine's intake air is increased, its temperature also increases. In addition, heat soak from the hot exhaust gases spinning the turbine will also heat the intake air. The warmer the intake air, the less dense, and the less oxygen available for the combustion event, which reduces volumetric efficiency.

To compensate for the increase in temperature, turbocharger units often make use of an intercooler between successive stages of boost to cool down the intake air.



Top-mount (TMIC) and Front-mount intercoolers (FMIC)

There are two areas on which intercoolers are commonly mounted. It can be either mounted on top, parallel to the engine, or mounted near the lower front of the vehicle. Top-mount intercoolers setups will result in a decrease in turbo lag, due in part by the location of the intercooler being much closer to the turbocharger outlet and throttle body.

Front-mount intercoolers have the potential to give better cooling compared to that of a top-mount. The area in which a top-mounted intercooler is located, is near one of the hottest areas of a car, right above the engine.

When the atmospheric temperatures begin to rise, top-mount intercoolers tend to underperform compared to that of a front-mount intercooler. With more distance to travel, the air circulated may have more time to cool and is located away from high temperature locations of the car, front-mount intercoolers can provide more beneficial cooling compared to that of a top-mount intercooler.

Water injection and Methanol Injection

Water Injection- In internal combustion engines, water injection, also known as anti-detonant injection (ADI), can spray water into the incoming air or fuel-air mixture, or directly into the cylinder to cool certain parts of the induction system where "hot points" could produce premature ignition. Depending on the engine, improvements in power and fuel efficiency can also be obtained solely by injecting water. Water injection may also be used to reduce NOx or carbon monoxide emissions

Methanol Injection - Turbocharged engines run high boost and high engine temperatures. When injecting the mixture into the intake stream, the air is cooled as the liquids evaporate and inside the combustion chamber it slows the flame, acting similar to higher octane fuel. Methanol/water mixture allows for higher compression because of the less detonation-prone and, thus, safer combustion inside the engine.

Wastegate

A wastegate regulates the exhaust gas flow that enters the exhaust-side driving turbine and therefore the air intake into the manifold and the degree of boosting. It can be controlled by a boost pressure assisted, generally vacuum hose attachment point diaphragm (for vacuum and positive pressure to return commonly oil contaminated waste to the emissions system) to force the spring-loaded diaphragm to stay closed.

Anti-surge/dump/blow off valves

Turbocharged engines operating at wide open throttle and high rpm require a large volume of air to flow between the turbocharger and the inlet of the engine. When the throttle is closed, compressed air flows to the throttle valve without an exit. The primary use of this valve is to maintain the spinning of the turbocharger at a high speed. The air is usually recycled back into the turbocharger inlet (diverter or bypass valves), but can also be vented to the atmosphere (blow off valve).

Tire Classification – Based on Application

Turbocharger Classification – Based on Application

- Petrol-powered cars
- Diesel-powered cars
- Motorcycles
- Trucks
- Aircraft

Petrol-powered cars

Turbochargers are commonly used in passenger cars to obtain greater power output from a given engine displacement.

New techniques such as twin-turbo/bi-turbo (whether parallel or sequential) setups and twin-scroll turbocharger, in combination with technologies such as variable valve timing and direct fuel injection, have cut down on turbo lag.

Note- Turbo lag is the delay between when you open the throttle and when the turbo begins delivering boost or in simple words a little hesitation you feel, when you press on the accelerator pedal and it takes a second for the engine to respond.

Diesel-powered cars

The first production turbocharger diesel passenger car was the Garrett-turbocharged Mercedes 300SD introduced in 1978. Today, most automotive diesels are turbocharged, since the use of turbocharging improved efficiency, driveability and performance of diesel engines, greatly increasing their popularity. The Audi R10 with a diesel engine even won the 24 hours race of Le Mans in 2006, 2007 and 2008.

Motorcycles

The first example of a turbocharged bike is the 1978 Kawasaki Z1R TC. Since 1980, few turbocharged motorcycles have been produced. This is partially due to an abundance of larger displacement, naturally aspirated engines being available that offer the torque and power benefits of a smaller displacement engine with turbocharger.

Trucks

The first turbocharged diesel truck was produced by Swiss Machine Works Saurer in 1938.

Aircraft

A natural use of the turbocharger — and its earliest known use for any internal combustion engine, starting with experimental installations in the 1920s , is with aircraft engines. As an aircraft climbs to higher altitudes the pressure of the surrounding air quickly falls off. At 5,486 m (18,000 ft), the air is at half the pressure of sea level and the airframe experiences only half the aerodynamic drag. However, since the charge in the cylinders is pushed in by this air pressure, the engine normally produces only half-power at full throttle at this altitude. Pilots would like to take advantage of the low drag at high altitudes to go faster, but a naturally aspirated engine does not produce enough power at the same altitude to do so.

Turbocharger - Business and adoption

Business and adoption

Honeywell turbo Technologies, Borg Warner and Mitsubishi Turbocharger are the largest manufacturers in Europe and the United States. Several factors are expected to contribute to more widespread consumer adoption of turbochargers, especially in the US.

In India, while ICRA (Investment Information and Credit Rating Agency of India Limited) expects penetration of diesel PV to stabilize at about 35% level over the medium term (from 40% plus level currently), the increasing usage of turbochargers in petrol engine will continue to support the Indian turbocharger industry.

THANK YOU

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Are there any Questions?