TURBOCHARGERS

When people talk about race cars or high-performance sports cars, the topic of **turbochargers** usually comes up. Turbochargers also appear on large diesel engines. A turbo can significantly boost an engine's horsepower without significantly increasing its weight, which is the huge benefit that makes turbos so popular!

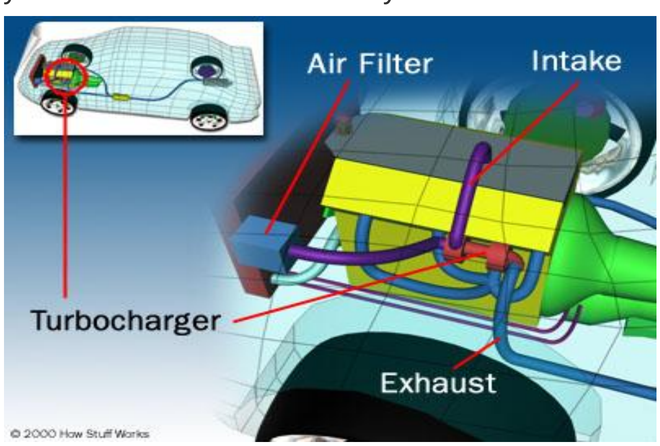
In this article, we'll learn how a turbocharger increases the power output of an engine while surviving extreme operating conditions. We'll also learn how wastegates, ceramic turbine blades and ball bearings help turbochargers do their job even better. Turbochargers are a type of **forced induction system**. They **compress** the air flowing into the engine (see How Car Engines Work for a description of airflow in a normal engine). The advantage of compressing the air is that it lets the engine squeeze more air into a cylinder, and more air means that more fuel can be added. Therefore, you get more power from each explosion in each cylinder. A turbocharged engine produces more power overall than the same engine without the charging. This can significantly improve the power-to-weight ratio for the engine (see How Horsepower Works for details).

In order to achieve this boost, the turbocharger uses the exhaust flow from the engine to spin a **turbine**, which in turn spins an **air pump**. The turbine in the turbocharger spins at speeds of up to 150,000 rotations per minute (rpm) -- that's about 30 times faster than most car engines can go. And since it is hooked up to the exhaust, the temperatures in the turbine are also very high.

Keep reading to find out how much more power you can expect from your engine if you add a turbocharger.

Turbochargers and Engines

One of the surest ways to get more power out of an engine is to increase the amount of air and fuel that it can burn. One way to do this is to add cylinders or make the current cylinders bigger. Sometimes these changes may not be feasible -- a turbo can be a simpler, more compact way to add power, especially for an aftermarket accessory.



Where the turbocharger is located in the car.

Turbochargers allow an engine to burn more fuel and air by packing more into the existing cylinders. The typical boost provided by a turbocharger is 6 to 8 pounds per square inch (psi). Since normal atmospheric pressure is 14.7 psi at sea level, you can see that you are getting about 50 percent more air into the engine. Therefore, you would expect to get 50 percent more power. It's not perfectly efficient, so you might get a **30- to 40-percent improvement** instead.

One cause of the **inefficiency** comes from the fact that the power to spin the turbine is not free. Having a turbine in the exhaust flow increases the restriction in the exhaust. This means that on the exhaust stroke, the engine has to push against a higher back-pressure. This subtracts a little bit of power from the cylinders that are firing at the same time.

Turbocharger Parts

One of the main problems with turbochargers is that they do not provide an immediate power boost when you step on the gas. It takes a second for the turbine to get up to speed before boost is produced. This results in a feeling of lag when you step on the gas, and then the car lunges ahead when the turbo gets moving.

One way to decrease turbo lag is to reduce the **inertia** of the rotating parts, mainly by reducing their weight. This allows the turbine and compressor to accelerate quickly, and start providing boost earlier. One sure way to reduce the inertia of the turbine and compressor is to make the turbocharger smaller. A small turbocharger will provide boost more quickly and at lower engine speeds, but may not be able to provide much boost at higher engine speeds when a really large volume of air is going into the engine. It is also in danger of spinning too quickly at higher engine speeds, when lots of exhaust is passing through the turbine.

Turbochargers provide boost to engines at high speeds.

A large turbocharger can provide lots of boost at high engine speeds, but may have bad turbo lag because of how long it takes to accelerate its heavier turbine and compressor. Luckily, there are some tricks used to overcome these challenges.

Most automotive turbochargers have a **wastegate**, which allows the use of a smaller turbocharger to reduce lag while preventing it from spinning too quickly at high engine speeds.

The wastegate is a valve that allows the exhaust to bypass the turbine blades. The wastegate senses the boost pressure. If the pressure gets too high, it could be an indicator that the turbine is spinning too quickly, so the wastegate bypasses some of the exhaust around the turbine blades, allowing the blades to slow down.

Some turbochargers use **ball bearings** instead of fluid bearings to support the turbine shaft. But these are not your regular ball bearings -- they are super-precise bearings made of advanced materials to handle the speeds and temperatures of the turbocharger. They allow the turbine shaft to spin with less friction than the fluid bearings used in most turbochargers. They also allow a slightly smaller, lighter shaft to be used. This helps the turbocharger accelerate more quickly, further reducing turbo lag.

Ceramic turbine blades are lighter than the steel blades used in most turbochargers. Again, this allows the turbine to spin up to speed faster, which reduces turbo lag.

Using Two Turbochargers & More Turbo Parts

Some engines use **two turbochargers** of different sizes. The smaller one spins up to speed very quickly, reducing lag, while the bigger one takes over at higher engine speeds to provide more boost.

When air is compressed, it heats up; and when air heats up, it expands. So some of the pressure increase from a turbocharger is the result of heating the air before it goes into the engine. In order to increase the power of the engine, the goal is to get more air molecules into the cylinder, not necessarily more air pressure.

TOSHIFUMI KITAMURA/AFP/Getty Images

A Mazda RX-8 rotary coupe fitted with an aftermarket turbocharger system.

An **intercooler** or **charge air cooler** is an additional component that looks something like a radiator, except air passes through the inside as well as the outside of the intercooler. The intake air passes through sealed passageways inside the cooler, while cooler air from outside is blown across fins by the engine cooling fan.

The intercooler further increases the power of the engine by cooling the pressurized air coming out of the compressor before it goes into the engine. This means that if the turbocharger is operating at a boost of 7 psi, the intercooled system will put in 7 psi of cooler air, which is denser and contains more air molecules than warmer air.

A turbocharger also helps at **high altitudes**, where the air is less dense. Normal engines will experience reduced power at high altitudes because for each stroke of the piston, the engine will get a smaller mass of air. A turbocharged engine may also have reduced power, but the reduction will be less dramatic because the thinner air is easier for the turbocharger to pump.

Older cars with carburetors automatically increase the fuel rate to match the increased airflow going into the cylinders. Modern cars with fuel injection will also do this to a point. The fuel-injection system relies on oxygen sensors in the exhaust to determine if the air-to-fuel ratio is correct, so these systems will automatically increase the fuel flow if a turbo is added.

If a turbocharger with too much boost is added to a fuel-injected car, the system may not provide enough fuel -- either the software programmed into the controller will not allow it, or the pump and injectors are not capable of supplying it. In this case, other modifications will have to be made to get the maximum benefit from the turbocharger.