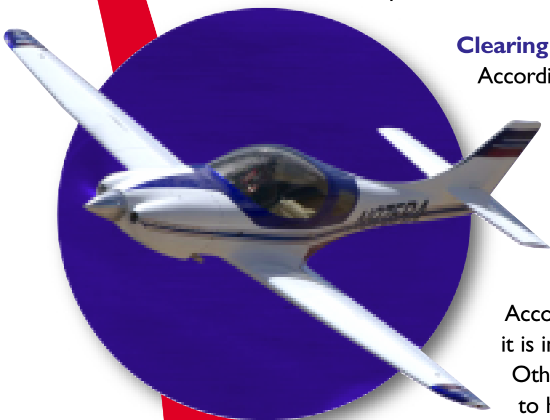
Supercharging vs. Turbocharging in aircraft

It's one of the most common questions we are asked the answer to which is almost impossible to find: "What is better—a supercharger or a turbo?"

We only wish the answer were that simple, but unfortunately it is not. The simple answer is: "It depends."

But don't worry, we'll go into more depth than that here. Both superchargers and turbos have distinct advantages and disadvantages. Selecting the right kind of forced induction for your vehicle will depend upon your particular vehicle, your driving habits, your power preferences, and your needs.



Clearing Up Confusion

According to Merriam-Webster's dictionary, a supercharger is defined as: "a device (as a blower or compressor) for pressurizing the cabin of an airplane or for increasing the volume air charge of an internal combustion engine over that which would normally be drawn in through the pumping action of the pistons".

A turbocharger is defined as: "a centrifugal blower driven by exhaust gas turbines and used to supercharge an engine".

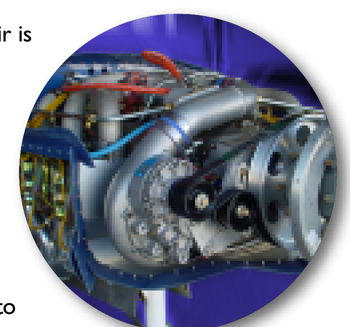
According to Webster's, a turbocharger is included in the definition for superchargers—it is in fact a very specific type of supercharger—one that is driven by exhaust gasses. Other superchargers that do not fall into this category—the kind that we are all used to hearing about - are normally driven directly from the engine's crankshaft via a crank pulley. So in reality, it is not fair to compare all superchargers to turbochargers, because all turbochargers are also superchargers. For the purpose of this discussion, however, a supercharger will be considered all superchargers that are are not driven directly by the engine, while turbochargers will be considered all superchargers that are driven by engine exhaust gasses.

Similarities

Both superchargers and turbochargers are forced induction systems and thus have the same objective—to compress air and force more air molecules into the engine's combustion chambers than would normally be allowed at atmospheric pressure here on Earth (14.7 psi at sea level). The benefit of forcing more air molecules into the combustion chambers is that it allows your engine to burn more fuel per power stroke. With an internal combustion engine, burning more fuel means that you convert more fuel into energy and power. For this reason, supercharged and turbocharged engines normally produce 40% to 100%+ more power (depending on the amount of boost—check out our horsepower calculator) than normally aspirated engines.

How They Work

A supercharger is mounted to the engine and is driven by a pulley that is inline with the crank (or accessory) belt. Air is drawn into the supercharger and compressed by either an impeller (centrifugal-style supercharger), twin rotating screws (screw-type supercharger), or counter-rotating rotors (roots-type supercharger). The air is then discharged into the engine's intake. Faster crank speed (more engine rpm) spins the supercharger faster and allows the supercharger to produce more boost (normally 6 to 9 psi for a street vehicle). Typical peak operating speeds for a supercharger are around 15,000 rpm (screw-type and roots style superchargers) and 40,000 rpm (centrifugal-style superchargers).



A turbocharger operates in much the same way as a centrifugal (internal impeller) supercharger, except it is not driven by pulleys and belts attached to the engine's crank. A turbo is instead driven by exhaust gasses that have been expelled by the engine and are travelling through the exhaust manifold. The exhaust gas flows through one half of the turbocharger's turbine, which drives the impeller that compresses the air. Typical operating speeds of a turbocharger are between 75,000 and 150,000 rpm.

Head to Head Comparison

Now it's time to evaluate the turbocharger versus the supercharger according to several important factors.

Cost

The cost of supercharger and a turbocharger systems for the same engine are approximately the same, so cost is generally not a factor.

Lag

This is perhaps the biggest advantage that the supercharger enjoys over the turbo. Because a turbocharger is driven by exhaust gasses, the turbocharger's turbine must first spool up before it even begins to turn the compressor's impeller. This results in lag time which is the time needed for the turbine to reach its full throttle from an intermediate rotational speed state. During this lag time, the turbocharger is creating little to no boost, which means little to no power gains during this time. Smaller turbos spool up quicker, which eliminates some of this lag. Turbochargers thus utilize 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 boost pressure, and if it 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.

A Supercharger, on the other hand, is connected directly to the crank, so there is no "lag". Superchargers are able to produce boost at a very low rpm, especially screw-type and roots type blowers.

Efficiency

This is the turbo's biggest advantage. The turbocharger is generally more economical to operate as it as it is driven primarily by potential energy in the exhaust gasses that would otherwise be lost out the exhaust, whereas a supercharger draws power from the crank, which can be used to turn the wheels. The turbocharger's impeller is also powered only under boost conditions, so there is less parasitic drag while the impeller is not spinning.
The turbocharger, however, is not free of inefficiency as it does create additional exhaust backpressure and exhaust flow interruption.

Heat

Because the turbocharger is mounted to the exhaust manifold (which is very hot), turbocharger boost is subject to additional heating via the turbo's hot casing. Because hot air expands (the opposite goal of a turbo or supercharger), an intercooler becomes necessary on almost all turbocharged applications to cool the air charge before it is released into the engine. This increases the complexity of the installation. A centrifugal supercharger on the other hand creates a cooler air discharge, so an intercooler is often not necessary at boost levels below 10psi. That said, some superchargers (especially roots-type superchargers) create hotter discharge temperatures, which also make an intercooler necessary even on fairly low-boost applications.

Surge

Because a turbocharger first spools up before the boost is delivered to the engine, there is a surge of power that is delivered immediately when the wastegate opens (around 3000 rpm). This surge can be damaging to the engine and drivetrain, and can make the vehicle difficult to drive or lose traction.

Back Pressure

Because the supercharger eliminates the need to deal with the exhaust gas interruption created by inserting a turbocharger turbine into the exhaust flow, the supercharger creates no additional exhaust backpressure. The amount of power that is lost by a turbo's turbine reduces it's overall efficiency.

Noise

The turbocharger is generally quieter than the supercharger. Because the turbo's turbine is in the exhaust, the turbo can substantially reduce exhaust noise, making the engine run quieter. Some centrifugal superchargers are known to be noisy and whistley which, annoys some drivers (we, however, love it!)

Reliability

In general, superchargers enjoy a substantial reliability advantage over the turbocharger. When a a turbo is shut off (i.e. when the engine is turned off), residual oil inside the turbo's bearings can be baked by stored engine heat. This, combined with the turbo's extremely high rpms (up to 150,000rpm) can cause problems with the turbo's internal bearings and can shorten the life of the turbocharger. In addition, many turbos require aftermarket exhaust manifolds, which are often far less reliable than stock manifolds.

Ease of Installation

Superchargers are substantially easier to install than a turbos because they have far fewer components and simpler devices. Turbos are complex and require manifold and exhaust modifications, intercoolers, extra oil lines, etc.— most of which is not needed with most superchargers. A novice home mechanic can easily install most supercharger systems, while a turbo installation should be left to a turbo expert.

Maximum Power Output

Turbos are known for their unique ability to spin to incredibly high rpms and make outrages peak boost figures (25psi+). While operating a turbocharger at very high levels of boost requires major modifications to the rest of the engine, the turbo is capable of producing more peak power than superchargers.

Tunability

Turbochargers, because they are so complex and rely on exhaust pressure, are notoriously difficult to tune. Superchargers, on the other hand, require few fuel and ignition upgrades and normally require little or no engine tuning.

Conclusion

While the supercharger is generally considered to be a better method of forced induction for most street and race vehicles, the turbo will always have its place in a more specialized market. Superchargers generally provide a much broader powerband that most drivers are looking for with no "turbo lag". In addition, they are much easier to install and tune, making them more practical for a home or novice mechanic.

We hope you have found this discussion informative and unbiased. Sometimes when we explain this to our customers, they say that we are biased towards superchargers because that is all we carry. We remind those customers that a turbo is a kind of supercharger and that we truly hope to carry turbochargers someday. The reason we do not currently sell any turbochargers is because we have not yet found a turbo system that is suitable for mail-order/e-commerce sale. We are not prepared to sell a turbo system that is difficult to install and requires the attention of a professional engine tuner or mechanic.
If any turbocharger manufacturer makes such a system, please send us the details as we would love to carry such a product.

The Great Debate.

At a Fly In the other Saturday (they are the ones that you just have to go to!), I overhead a couple of pilots arguing the differences between a "superchargers" and a "turbochargers". After listening for a while, I just wandered off because I didn't want to get mixed up in that one. Afterwards though, I kept thinking things like; "Well, both of them are pumps, the same as the engine, when you get right down to it. The 'suck' and 'squeeze' part of the four strokes are, anyway."

I would like to explore the basic differences between these two devices, both of which have been designed to boost engine performance. In the early days, turbochargers were quite large and were only used on the larger diesel engines and WWII aircraft that ran at a fairly constant and relatively low speed. Around these times, the supercharger was all the rage for gas engines either fitted as power enhancement devices for high altitude fighter and bomber aircraft.

Superchargers roots type

Looking at this device first, there has been a variety of different designs developed over the years; the Roots type supercharger seems to have been the main stayer. The internals are curved and fluted rotors that, while running very close to each other, don't actually touch.

The rotors are timed to each other by a pair of precision spur gears pressed onto the rotor shafts. At the forward end, the rotors are supported and held in position by deep groove ball bearings, while sealed roller bearings are used at the rear.

Supercharger vs. Turbochargers

A generally held opinion about superchargers is that they take power from the engine to drive them, so they are not really all that efficient. Without getting into comparative graphs and so on, just let me say that the increased power output from an engine that is supercharged (even lightly), is far and away superior to the same engine without it!

Some claimed advantages of using a supercharger over a turbocharger are that, as this is belt driven from the engine crankshaft, the boost response is immediate and the supercharger operates in an environment where high exhaust temperatures are not in close proximity.
On that point then, let's now turn our attention to the exhaust driven.

Turbochargers

The turbocharger consists of a turbine, driven by the exhaust gases and a compressor wheel, connected to the turbine on a common shaft.

The concept is just so simple! You know that the exhaust gases at the outlet of the exhaust manifold are extremely hot and heat means energy.

Why not convert some of this energy into useful work by driving a turbine wheel. Something for nothing, what better!

Unfortunately (as with most brilliant ideas), there is a downside (well, several really). Let's check some of these out.

High Temperatures

Not only is this heat from the exhaust useful to us but it also has a down side, in that temperatures well over the 1,000°C mark are not uncommon and that plays havoc with the turbine wheel.

As development of turbochargers has continued, the material used for the turbine is now changing from nickel alloy, heat resistant steels to ceramic materials. Not only are they lighter but they can also stand up to those high temperatures very well.

Bearing Lubrication

Not only does the heat around the exhaust cause problems with bearing lubrication but also the speeds the turbine spins at, add to the situation. When you consider that the shaft can easily be spinning at speeds over 100,000 rpm when the thing is really singing, then I'm sure you can understand that the bearings have to be something special.

In fact, they are simple, plain bearings, but they are fully floating, with oil lubricating both sides.

To stop the hot gases from turning the oil to carbon, not only is there a constant flow of engine oil but also the turbine housings should be water cooled (not available in aircraft today) and then there is an effective seal between the bearing and the turbine wheel.

Pressure Control

So, why doesn't the pressure just keep building with an increase in engine speed? A "Wastegate Control Valve" is required to control boost. As the air pressure developed by the compressor wheel builds up with engine speed, the intake manifold pressure is also fed to the underside of the diaphragm in the wastegate valve.

When this pressure builds to the design point, the diaphragm moves against spring force and opens a valve in the exhaust stream. When this happens some of the exhaust gas from the engine will bypass the turbine wheel and go straight down the exhaust pipe.

This effectively reduces turbine speed and the pressure built up by the compressor. All very simple really.

Inertia

What this means is that something that is stopped tries to stay that way and something that is moving, also tries to keep right on moving, despite the outside forces being applied.

The problem for the turbocharger then, how to get it spinning quickly when the throttle is opened quickly and how do we stop it from spinning at a million MPH, when we want to a land?

Design is the answer to the first part, by using a split pulse, entry duct on the exhaust side. This allows the exhaust pulses at low engine speeds to build on one another and this helps the turbine to spin up at low engine speeds. Exhaust manifold design too, plays an important part in this whole process.

The second part of the speed question, is the reason that an engine should be left to idle for a minute or two, after a high speed run, to allow engine oil to continue to be pumped through those bearings, while the shaft speed slows down.

There's another aspect about compressing the intake air that I haven't touched on yet and it's an important one too, as it also relates to temperature.

Turbocharger Intercooler

Whenever air is compressed, it gets hot—witness to that is the bicycle pump after pumping up a tire. As the air temperature increases, the density of that air (at that pressure) is less dense, meaning that the air molecules are further apart. This also means that there will be less oxygen in that sample of air that will be around to help with the combustion process. Enter the Turbocharger Intercooler.

No, this is not just a marketing ploy to sell more planes (we've all seen the phrase, Turbocharger with Intercooler). It really does help. There are usually two types; Air to Air and Air to Water. Air-to-Air is used in aircraft. The idea of course, is to extract as much heat as possible from the compressed air before it enters the combustion chamber. Not only does this mean that the air is denser and has more oxygen in the same volume, but it will also be heavier! Remember what I said about inertia before? Once that cooler, heavier air is moving, it will want to continue doing that, even with the pressure behind it. The result is a 'ram air' effect to go with the pressured charge. A double whammy!

Mind you I don't think you would notice the difference from the seat of your pants while flying, but tests do show a marked improvement when intercooling is carried out.

I hope you can see now why I didn't buy into that animated discussion I mentioned at the start. I'm not about to say that one of these two forms of charge boosters is better than the other. Just let me say that either one, correctly engineered for the engine, will certainly boost the output or, depending on how it's set up, the torque curve will also flatten out.

Tech Tip: Turbochargers Vs. Superchargers—The Basics

Turbochargers and Superchargers both force more air and fuel into the combustion chamber to make more power. By "more air and fuel", I mean more than can be achieved by just the "sucking" of the piston on the intake stroke. The extra pressure they make is commonly measured in MAP.

Turbochargers and superchargers both use some sort of compressor or turbine as a sort of "pump" to do this.

A supercharger's pump is driven mechanically by a belt or gears off of the engine's crankshaft. As the motor runs, the crankshaft spins a belt or gears which spin the compressor or turbine, which pumps more air and fuel into the combustion chamber for more power. Because of this direct link to the engine, superchargers typically produce boost pressure immediately, without "boost lag". Typically but not always—a supercharger with an overly big turbine or one that is undergeared can suffer from boost lag. Because a supercharger is hooked up mechanically to the engine, it uses a small amount of the engine's power to run. So, even though a supercharger might add 100 extra horsepower, it might be using up 10 to 20 horsepower just to mechanically spin the turbine. However, no matter how you slice it, you are still getting 100 extra horsepower.

A turbo's pump is driven by exhaust gas energy. As exhaust gas leaves the combustion chamber and goes out the exhaust manifold, it is fed into a turbo. The turbo has two separate chambers. The exhaust gas flows into one chamber, causing a turbine to spin, then exits the chamber and out the exhaust system. The spinning turbine is connected by a shaft to the second chamber, where is spins a compressor wheel that pumps intake air through the intake tract and into the combustion chamber. Because turbos rely on exhaust gas energy to make boost, they can sometimes suffer from "boost lag" as the turbo waits for exhaust pressure to build before pressure and power is produced. However, with proper sizing of the turbo and exhaust plumbing, "boost lag" can be avoided. Because a turbo uses exhaust gas energy to spin the turbine (energy that would otherwise be lost out of the tailpipe, unused), it does not use up any of the engine's power the way a supercharger does.

Because the turbo uses exhaust gas energy to make more power, and more power produces more exhaust gas energy, in theory a turbo will produce more and more MAP in a cycle until the engine can't take any more and blows to smithereens (a bit of an over-simplification). This is why turbos need a wastegate to control boost pressure. When the wastegate senses that the boost pressure has gone over a predetermined MAP, it opens up and "leaks" the extra pressure out, keeping the MAP at a safe level.

Superchargers vs. Turbochargers

Both supercharging and turbocharging use a compressor to force more air into the combustion chambers of an engine, hence the term "forced induction". The main difference between them is:

A turbocharger is driven by exhaust gasses and has to "spool up" before delivering its boost. It's lubrication system is dependent upon engine oil pressure.

A supercharger is belt driven off of the crankshaft and begins to deliver boost as soon as you accelerate, depending upon the design of the supercharger's controller. Its boost is delivered in direct proportion to engine speed. It is not in contact with heated exhaust gasses so it doesn't need to be piped into intercooler systems.

With a supercharger—there is no lag!

All Superchargers are Not the Same

There are three major types of superchargers: Roots type, Centrifugal type, and Lysholm Twin-screw type. These are all evaluated and rated according to their adiabatic and volumetric efficiencies.

Roots type blowers use interlocking identical lobes that pushes air into the intake manifold where it is compressed, or "boosted". Once positive manifold pressure is achieved, it can cause some blow-back into the compressor.

Centrifugal type blowers are virtually belt driven turbochargers. They need time to spool up and deliver their boost higher in the engine rev range.

Superchargers Vs Turbochargers

Superchargers are driven by a pulley system, while a Turbocharger is driven by exhaust gases. The main differences are;

- A Superchargers power comes in at low rpm due to the fact it doesn't need exhaust gases to spin the turbine to make boost. This makes superchargers very responsive on take off and climb.
- Also the compressor does not spin anywhere near as fast as a turbocharger, so the intake gases are cooler then what you would find on a turbocharger.
- Turbochargers do have advantages, they create more power up top (over 20,000 FT.)

Unfortunately on hot days, S/C and more so T/C planes suffer power loss. This is caused by the density of the compressed air. Hotter the air, the less dense it is.

Intercoolers

Intercoolers are designed to cool the heated air that is coming form the outlet of the Turbo or Supercharger. This is a very effective way of increasing air density which creates more power. But there is a myth about intercoolers. The bigger the intercooler doesn't mean its going to be better.

Long narrow intercoolers normally flow no where near as well as a short fat intercooler. The longer the core, the more restrictions to the air flow. This increases the turbo lag.
The overall efficiency of the core is judged by its design, not by its size.

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