Comparing and Evaluating Supercharger Impellers

By

Carl Fausett
Member S.A.E.
928 Motorsports, LLC

Copyright 2016, 2019
Carl A Fausett and
928Motorsports, LLC

All Rights reserved
- Qualifications -

Carl Fausett is an engine builder and performance parts developer with more than 30 years of experience in domestic and imported automobiles, starting in 1976.

In the last 16 years, he has successfully developed supercharger kits for every Porsche 928 16v and 32v model, the Ferrari 308, 328 and Mondial, and the Porsche 968.

While doing this, he found the need to get more HP out of the superchargers that would fit into the small confines of the available space he had on these cars. He hired the industries top impeller designer, and together they developed and patented new impellers for Powerdyne, Paxton, and Vortech superchargers that out-perform the stock impellers by as much as 20%.

For this work, he received U.S. patents number D554,150 S and D588,158

He is a contributor to Engine Builder magazine, and holds the world record for the fastest Porsche 928 in the world, featuring a 1114 HP Porsche 928 engine he built.

Frequently quoted and published, Carl has had featured articles published in these magazines in the last several years:
- Engine Builder Magazine
- Excellence Magazine
- 9 Magazine
- Motorfest magazine
- Porsche & 911 Magazine
- Machine Design Magazine
- American Chemical Society

...and numerous websites such as:
- Road & Track.com
- Engine Swap.com
- Engine Labs.com
THE MANUFACTURING METHOD
Cast and Billet Processes described

HOW TO IDENTIFY CAST AND
BILLET IMPELLERS I & II

SHAPE OF THE VANES
Predicting flow and pressure

FITMENT TO THE VOlUTE
The ability to make pressure

IMPELLER COATINGS
Fighting heat, abrasion, and corrosion

WEIGHT AND BALANCE
Stress on internal and external components

A CASE STUDY
A side-by-side comparison of two impellers

CONCLUSION
Putting it all together
The manufacturing method

Cast and Billet Processes Described

We need to spend just a moment to discuss these terms: “billet” and “cast” in broad brushstrokes as it pertains to the topic at hand, impellers. In the metal business, any square or rectangular chunk of metal is called a “billet”, and a round chunk is called a “round”. But the word billet in aftermarket parts has become abused to suggest “stronger because it is made from billet.” This is not always true. Inferior materials and manufacturing techniques will still make inferior parts.

For the non-engineers in the audience: A cast part is made from liquid material being forced or poured into a mold. The part will necessarily have thicker and thinner areas, and takes its shape from the mold in this molten state. Therefore the material or alloy chosen must have good castability. One of the main properties of a material that has good castability is that it flows well into the mold, and that it does not form internal voids as it cools. The alloys that are good for casting are typically weaker and more brittle.

Now the billet... billet parts have the capability of being of higher strength than a cast part. It depends on what kind of material (alloy) the billet is made from. A billet part is cut (via milling, lathing and tooling) from a solid billet, so the material does NOT have to be castable. This allows the use of high-strength alloys. Again, where after-market parts are concerned, this does not stop the manufacturer from picking a weak, cheap material, knowing some gear-heads will buy the part just because the box says it is made from “billet” – so be careful.

Aluminum has a broad range of alloys— those used in the casting process are often in the 1000 and 2000 series. The stronger alloys for billet machining are in the 6000 and 7000 series.

Let’s go back to our impeller. The primary stresses on this part come from a bending moment as the vanes are pushed backwards by their attempt to pack air into a tube that has back-pressure (and resistance to flow). There are other stresses, but let’s focus just on this one.

Looking at this bending moment, the 2014-0 alloy frequently used in castings will yield at 14,000 psi and fail at 27,000 psi. In the same thickness, the 7075-T651 aerospace-grade aluminum we use in our impellers has a yield strength of 73,000 psi and an ultimate fail strength of 83,000 psi.

So you can see, the alloy means more than the fact that it is made from billet alone. Ask what alloy they used to make your impeller—a quality manufacturer will tell you. Remember how thin the vanes are—and a broken vane can get ingested and ruin an entire engine!
How to Identify Cast and Billet Impellers I

Here is a close-up of a typical cast impeller. You can see the stippled finish left behind by the casting mold.

Another test: If you snap the impeller vane of a cast impeller with your finger, it will make a dead “thud” sound.

Here is a close-up of a poorly made billet impeller. You can see the widely spaced machining paths. The alloy used is soft and gummy and does not machine well so the edges of the cuts are rounded.

When you snap these vanes with your finger, it will make a dull “thud” sound also.

Here is a close-up of a well-made billet impeller. Note the fine machining lines that are very close to each other. Also note the sharpness of the edges of the cuts because the alloy used is strong and not soft.

When you snap these vanes with your finger you will hear a definite “ting” similar to a fine goblet or a bell.
How to Identify Cast and Billet Impellers II

Here is a simple rule: the job of the impeller is to move AIR. True. And everywhere there is metal, there cannot be air. Also true.

If a weak alloy is used to make the impeller, the vanes have to be thick so they do not break under load (Yellow Arrows below). Also, the impeller floor is often higher when a weaker alloy is used so the vanes do not break off where they are attached to the floor (Green Arrows).

The impeller in the picture on the left is cut from billet, but they chose a poor (cheap) alloy. With its high floor and thick vanes, it will not perform much better than the stock impeller and may actually be worse.

These two impellers fit the same supercharger.

The impeller on the left side of this picture is the stock cast impeller. Casting alloys are also not as strong, so compromises from an ideal design had to be made. Again, higher floors, shorter vanes, and thicker vanes.

The impeller on the right is made from 7075-T651 which is very strong, so it can be shaped to move a lot more air without compromise. Lower floor, thinner vanes, and more room for air.
Shape of the Vanes

Predicting flow and pressure

There are a few simple observations of the impeller vane and shape that you can make without having a degree in fluid dynamics.

For example, in general terms, an impeller with straight vanes will not provide boost until it is turning much faster than an impeller with aggressively curled vanes that grab and push air better at lower speeds. This translates into how low in the rpm range the supercharger can start to make boost.

This impeller has taken some steps in the right direction, and has some curl at the inlet to help it move air in the lower RPM’s.

But at the exducer, or exit, it has allowed the vanes to go straight again. This allows the air to slow down as it exits, and will reduce the pressure it can make at high rpm’s. Also, notice the vanes are straight up-and-down as compared to...

...this impeller which features aggressively curled and progressive vanes through the entire length of the vane, even at the exducer where that last little curve provides a “push” that will help high rpm performance.

Note too that the vanes are angled, so the air is captured and must move where we want it to and cannot simply spill over the vane to the next chamber. For these reasons this impeller will produce higher pressure numbers than the one above it, which it replaces.
FITMENT TO THE VOLUTE

THE ABILITY TO MAKE PRESSURE

Between the inlet (inducer) and the outlet (exducer), the impeller vane must very closely follow the shape of the volute. If the outer edge of the vane is allowed to move away from the volute, pressure will be lost.

In addition, because the air will tumble over the top of the vane into the next compartment (and again and again ad infinitum), there will be a marked increase in the temperature of the charged air and decrease in adiabatic efficiency¹.

Superchargers are measured in adiabatic efficiency to represent how efficient they are at compressing the air without putting a lot of heat into it.

For example: a supercharger with 85% adiabatic efficiency is more efficient than a supercharger with 75% adiabatic efficiency, and will not heat up the charge air as much. Poor impeller designs and fitment will lower the efficiency of the supercharger, increasing the heat and lowering the HP.

¹Adiabatic efficiency explained: as air is compressed, it gets hotter. Hot air is less dense than cool air, so it will make less HP. In addition, feeding an engine hot air reduces engine safety because it can lead to pre-ignition and engine damage.
Impeller Coatings
Fighting Heat, Abrasion, and Corrosion

LESS HEAT TRANSFER
The surface coating is insulative and doesn’t transfer heat as quickly as a naked aluminum impeller does. This works in both directions – in low boost applications the heat of the gear housing is transferred up the shaft into the impeller and this heats the air. That hurts performance and can contribute to engine damage. In high boost applications, the heat in the compressor area is transferred down the shaft into the bearings, shortening their life.

RESISTANCE TO ABRASION
Small sand particles get through the air filter and they shot-peen the impeller, causing damage to the surface and lowering output. A coated impeller is much more impact and scratch resistant than a naked one.

RESISTANCE TO CORROSION
Uncoated impellers oxidize and corrode causing drag and weakening the impeller. This makes the engine work harder and increases parasitic loss.

These impellers are so badly corroded they are on their way to the dumpster!
WEIGHT and BALANCE
STRESS ON INTERNAL AND EXTERNAL COMPONENTS

WEIGHT: Because the supercharger (and the impeller inside) is connected to the engine by a drive belt, it must accel and decel every time the engine does. With each up-shift or down-shift the engine suddenly changes speed and the impeller is forced to do the same.

A heavy impeller has more mass, and stores more kinetic energy. This is sometimes referred to as the “flywheel effect” and it is not what you want in an impeller. A heavy impeller is harder to accelerate and decelerate, and contributes to belt slip in the drive system as a result of this. It will make the engine less responsive, and add to the parasitic load on the engine by the supercharger.

A lighter impeller on the other hand can change speeds quickly with less load on the drive system, will have fewer problems with belt slip, and will contribute to a more responsive engine.

Here are three impellers that all fit the same supercharger. The one on the top left is the OEM cast impeller. The second is a poor quality after-market “billet” impeller that’s just as heavy as the cast impeller. The third is a high quality billet impeller that, because of the good alloys, design, and machining quality is 20% lighter. Saving 2 ounces on a 10 ounce part is a lot! This impeller will spin up and spin down faster, and reduce belt slip too.

Here’s another bad after-market impeller that was sent to us for installation. At just about 2 pounds, we called it “the wood chipper” but its more likely to eat engines and belts than wood.
Weight and Balance

Stress on Internal and External Components

Balance: At the speeds that impellers are spun, even very small amounts of out-of-balance becomes destructive to the bearings and the impeller itself. For example, we balance the tires on our cars because we know that a wheel and tire combo that is 1 ounce out of balance at 60 MPH will hit the pavement with nearly 10 pounds of force every time it rotates. Yet, that’s only turning at about 840 rpm for a typical 17” tire. Now imagine the effects of an out-of-balance impeller spinning at 50,000 rpm!

Where the vibrations in the out-of-balance tire will cause a nuisance and premature tire wear, the vibrations caused by an out-of-balance impeller will cause bearing failure, allowing the impeller to move axially and radially until it strikes the volute. In severe cases, the out-of-balance condition may even cause the impeller to fly apart. In either event, the resulting metal shrapnel coming out of the supercharger will be ingested by the engine and can create a very expense repair.

Look for balancing marks on the front and back of your impeller. If it was manufactured well, it should be pretty close to symmetrical in all directions and need only a slight amount of material removed in very few places to bring it into balance. If it was made badly or balanced badly, you are likely to see massive amounts of metal removed in many places.

This impeller was balanced with many holes and some grinding in a wide pattern and had a lot of material removed. Not a good sign.

The customer put it into service, the out-of-balance impeller ruined the bearings, and that allowed the impeller to hit the volute. You can see the damage done. That metal went into the motor!

Because of the speeds involved your supercharger impeller should be spin balanced to 0.006 grams/inch, and designed to operate up at speeds at least 10% higher than the bearings ratings for that supercharger. In addition, a good manufacturer will perform a destructive speed test on their impeller where they will deliberately over-spin it at 10% (standard) or even 20% over its design limit to confirm that it will stay together.
A Case Study

A side-by-side comparison of two impellers

These two impellers are designed for the same model of supercharger. The badly damaged supercharger was sent along with this after-market impeller with a note to “fix it”. The original cast impeller is on the left, and the after-market impeller that the customer bought and installed is on the right.

A quick look at the “performance” impeller he purchased shows very wide vanes, very poor machining, a bad exit profile (straight vanes) and an incredibly bad attempt at balancing. The aluminum used was a soft and cheap alloy selected for low cost and rapid machining, not for a good quality final product.

The scale shows the rest... where the stock impeller weighed 10.46 ounces, the “performance” impeller weighed in at a whopping 18.70 ounces.

The damage this impeller caused cost the customer much more than the price of a good impeller from a reputable manufacturer.
CONCLUSION
PUTTING IT ALL TOGETHER

A good aftermarket impeller will be made from a high quality alloy for strength and will take advantage of that strength by having thin vanes and lower impeller floors.

The best alloys, like 7075, will have to be cut from billet. These alloys cannot be cast. But, just because an impeller is made from "billet" doesn't mean its made from a good alloy, so be careful there.

A high-performance impeller will have vanes that curl aggressively and progressively to grab and move more air at slower speeds than straight vanes will, and will achieve higher pressures.

A good impeller is light so it can change speeds rapidly, and well balanced to ensure long bearing life.

The performance impeller market has drawn in some quick-buck artists who are making really poor impellers and marketing them as a "billet" to those who do not know the difference.

Purchase your impeller from a reputable manufacturer who can explain the features, tell you what alloy they used, and to what rpm they were certified and balanced; and you will have a much more enjoyable supercharging experience.

Carl Fausett
Member S.A.E.