Engine Balancing - Tech - Balance of Power

Proper balancing of your engine's rotating assembly means better power and durability

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In addition to causing unnecessary failures in the main bearings, a race engine that isn't

When it is powering a race car--with all the rumbling, vibrations, beating, and banging going on--it can sometimes be easy to forget that the engine is a precision piece of equipment. In the hands of the right engine builder, all the moving pieces are as finely tuned and move with the precision of the proverbial Swiss watch.

That's a good thing. Because of the rpm being turned by race engines, any unbalance can have severe results. Two decades ago, if one piston and rod combination was heavier than the rest, it usually wasn't a problem. The entire mass of the rotating assembly was so much that a difference of 10 or more grams didn't make much difference. Today, however, component manufacturers are pushing the design limits of high-strength/low-weight components; a piston and rod combination that is just a few grams too heavy or light can mean ruined bearings, sheared flywheel bolts, and worse. That's why properly balancing your race engine's rotating mass is more important than ever before.

Calculating Weight

Here, the small end of the rod is being weighed to help determine the reciprocating weight. As you can see, the rod is assembled when it is weighed. A stationary arm suspends the end that isn't being weighed over the scale.

Here, the small end of the rod is being weighed to help determine the reciprocating weight.

Part of the difficulty with understanding how to balance an engine's rotating weight is this: Not all of it rotates. Yes, the crankshafts spins, but don't the pistons and part of the rods move up and down? How do you balance it all out?

The answer is actually a very simple calculation. When calculating the weight that is to be attached to the crank, the rod bearings and the big end of the rod are considered rotating weight. The small end of the rod, piston, wristpin, rings, and pin locks are all considered reciprocating weight (instead of spinning around, it moves up and down).

Typically, 100 percent of the rotating weight and 50 percent of the reciprocating weight are added together to form the total for the bob weight. Some engine builders include four or five grams in the total to simulate the weight of oil clinging to the various parts. The bob weights are actual weights that are attached to the crank's rod journals to simulate the weight of the rod/piston assembly. With the bob weights in place, the crank is ready to be spun on a balancing machine.

Understanding Overbalance

Earl Mark of Automotive Specialists checks each half of a bob weight individually to make sure that the total weight is correct, but also that both sides of the bob weight are equal.


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If you have hung around engine shops, then you may have heard that a crank has been "overbalanced." You may have even heard the phrase "underbalanced," but hopefully never in association with a circle track racing engine. Overbalancing is when the percentage of the reciprocating weight is increased by a couple of percentage points when calculating the bob weight. The idea is that this reduces high-rpm vibrations.

"There are always two critical imbalances in any V-8 engine," explains Keith Dorton, owner of Automotive Specialists. "Normally, there's a low-speed and a high-speed imbalance. Properly balancing the crankshaft reduces it, but it doesn't get rid of it.

"My first experience with overbalancing was early in my career with motorcycle engines. They were high rpm engines, and we were getting upto 60 to 70 percent overbalance on them to keep the high-rpm vibrations down.

"One of the first applications I remember overbalancing a V-8 was way back in the '60s on a big-block 427 Ford that was drag racing in the AGas class. Back then, it was making somewhere around 570 to 580horsepower.


Bob weights, which simulate the weight and motion of two rods, two pistons and the rest of

"The racer that ran the car was pretty much ahead of his time. Back then, the NASCAR guys were running their engines to 7,000 or at most7,200 rpm, but this guy was turning a big-block close to 8,000 in adragster. We balanced his rotating assembly using common practices for the time--50 percent reciprocating weight and 100 percent rotating weight. But he complained that when he really got the thing going in high gear, right before he got to the lights, the engine started vibrating so badly it actually blurred his vision.

"The high-rpm vibration was vibrating things off the car. In the short amount of time the car was on the track, the vibration was fatigue-cracking the sheet metal valve cover and the intake manifold. Plus, this driver had a really good feel for the car, and he could tell that when the engine got into this vibration, it was also laying down.

"So we brought the engine back in and overbalanced the crank. We overbalanced it at 52 percent (each bob weight weighed 100 percent of the rotating weight and 52 percent of the reciprocating weight), and it reduced the high-rpm vibration substantially. The next time we had it in the shop, we brought the overbalance up to 53 or 54 percent and that helped it even more. The change caused a pretty violent vibration in the low-rpm range. I think it was between 3,000 and 4,000, but that wasn't a concern because we weren't racing there. The change didn't just reduce the high-rpm vibrations. It decreased the elapsed time on the track, which is what we were really after."

For circle track racing, Dorton says that most engines are only overbalanced by a couple of percentage points. That's because an oval track car, especially for short tracks, will have to pull through a wide range of rpm. Although the engine may rev beyond 9,000 rpm, it will bein that range only for brief moments at the end of the straights. More important is how well the engine pulls at much lower rpm when the car is accelerating out of the turn. The goal is to adjust the components so that the critical vibrations fall at rpm levels below and above your normal operating range.

If your rules allow it, another option for removing metal is to angle the counterweights li

Piston and Rod Balancing

The first step in balancing an engine is weight-matching all the pistons and rods. To do this, all the components are weighed. The entire piston assembly, complete with rings and locks, can be weighed together, but the rods must be weighed in two stages. The small end and the big end of the rod must be weighed separately, since the small end falls under the reciprocating weight category while the big end is rotating weight. Seethe accompanying photo for how this is done.

When all the bob weights are correctly assembled and installed on the crank, a balancing ma

Now, compare the weights of the same components (for example, the small end of the rods). If they don't all weigh the same (within the range of a gram), the heaviest rods must have material cut away until they are the weight of the lightest rod. The same goes for the pistons and large end of the rods.

Fortunately, this practice only applies if you are racing with stock components. Today, almost all race-quality aftermarket components come weight-matched. Other than a quick check on the scales to make sure everything is OK and determine your bob weights, there is nothing for you to do. "With lightweight racing pistons and rods, there really isn’t any place you can remove material without harming the integrity of the component," Dorton says. "If you have a rod or piston that is way out of line on the weight, what you really have is an issue with your manufacturer."

Crank Balancing

Once the pistons and rod ends are all equal, the bob weights can be determined. With the bob weights attached to the crank's rod journals, a balance machine is used to specify exactly where the crank needs to be worked to bring it into balance. Whether they are forged or billet, most racing crank manufacturers can ship you a crank that's almost perfect if they know the component weights ahead of time. Weight is almost always added on the outermost throws because it makes the most difference in those locations.

Instead of drilling holes in the ends of the counterweights, Automotive Specialists prefers

A crank is brought into balance by either adding or removing weight in specific places. Since you don't want to increase the dimensions of the crank’s counterweights, adding weight is done by drilling out holes in the counterweights that run parallel to the crank's centerline and inserting slugs of "mallory metal." Mallory metal is a tungsten alloy that is 1.5 times heavier than lead, and a little goes a long way when balancing a crank.

The other method is to reduce weight. Many shops do this by drilling holes into the ends of the counterweights. This works fine, except many engine builders feel that the unevenness created in the ends of the counterweights increases windage. Dorton prefers to turn the ends of the counterweights down in a lathe so that the outside diameter (o.d.) of the crank is actually reduced. Final adjustments are done with a hand grinder and a light touch. This takes more time, but the end result is a racing crank with a smoother outer surface.

Calculating Bob Weights

Calculating bob weights isn't difficult, but it does require a little time at the scales. Here's the complete list for determining your bob weights for zero-balancing a crank.

Rotating Weight
* Big end of rod (including fastening hardware)
* Bearing
* Oil (normally estimated at four grams)

Reciprocating Weight
* Piston
* Wristpin
* Pin locks (if used)
* Small end of rod
* Piston rings

Bob weight = Rotating Weight + (Reciprocating Weight x .50)

This crank is essentially junk, but you can see the many slugs of mallory metal that have b

Internal versus External Balancing

So far, all of our discussion on balancing has included only the crank, pistons, rods, and the other various pieces that go into those assemblies. This is known as an internally balanced engine. The other option, an externally balanced engine, also includes the flywheel and harmonic damper. In this situation, both the flywheel and damper are installed on the crank when it is dynamically balanced on a balancing machine. Instead of modifying the crankshaft to achieve balance, weights are welded to the flywheel and/or the damper.

An externally balanced engine runs just as well as an engine that has been internally balanced, but this method isn't nearly as popular in racing. First, Dorton points out that if the damper were to break or come off, the main bearings could be damaged in a very short period of time. Then, instead of replacing just the damper, you would be looking at a complete engine rebuild. Second, because both the damper and flywheel are integral to the engine's balance, if either need to be replaced, the entire engine must be rebalanced. This isn't necessary in an internally balanced engine.