HOW TO BALANCE A ROTATING ASSEMBLY

Keeping Things Smooth for Max Power and Longevity

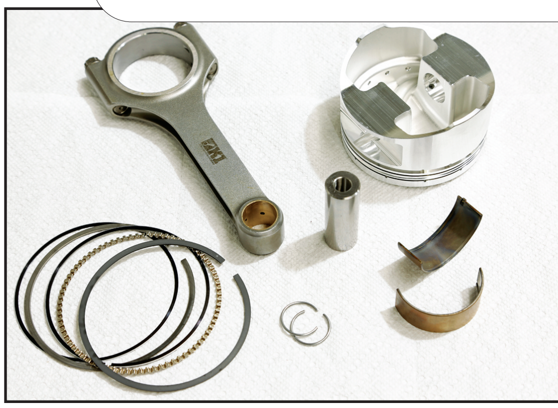
The Sunnen DCB 750 is one of the most commonly used balancers in the industry. It features two precision-calibrated stands that support the crank by its front and rear main journals. An electric motor spins the crank to 750 rpm with a belt that attaches to the center main journal. This allows sensors in the stands to measure the amount of imbalance in the front and rear of the crankshaft.

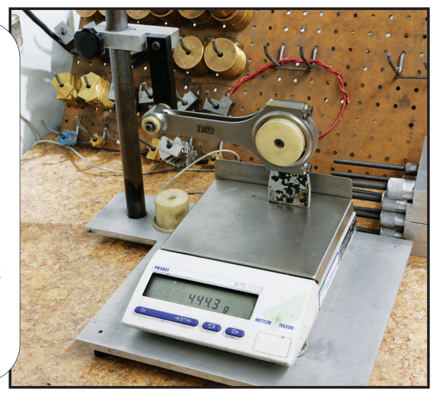
BY **STEPHEN KIM** PHOTOS **THE AUTHOR**

Properly balancing the rotating assembly in any engine build is paramount to maximizing performance and longevity, but few people get to watch the procedure firsthand. The consequences of getting it wrong range from merely annoying engine vibrations to catastrophic main bearing failure. To find out exactly what your friendly machine shop is doing to earn your $150, we headed down to the School of Automotive Machinists in Houston for a behind-the-scenes look.

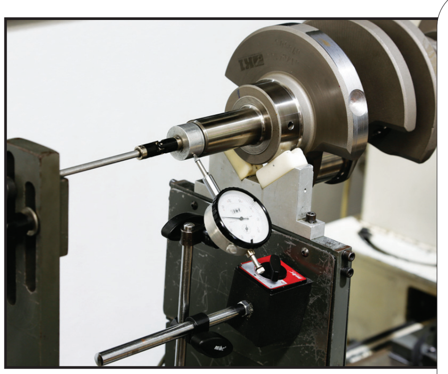
According to Judson Massingill, director of education at SAM, many of the preconceived notions regarding balancing are severely flawed. “The typical hot rodder will walk into an engine shop and say they want their rotating assembly balanced to one or two grams. What they think they want you to do is to make sure all the pistons and rods weigh within a couple of grams of each other, but most quality aftermarket manufacturers already do that at the factory,” he explained. “The real goal of balancing a rotating assembly is to make sure that the crankshaft counterweights offset the rotating and reciprocating forces created by pistons and rods. With today’s lightweight pistons and rods, accomplishing this usually involves removing mass from the crank counterweights.”

The pistons, rings, wrist pins, pin locks, and the small end of the connecting rods move up and down the bores, and comprise the reciprocating mass of a rotating assembly. The big end of the rods and the rod bearings rotate around the crankshaft centerline, and therefore represent the rotating mass. Since the goal of balancing is to equalize the rotating mass of the crankshaft counterweights to the rotating and reciprocation mass of rods and pistons, each of these components must be measured on a scale.

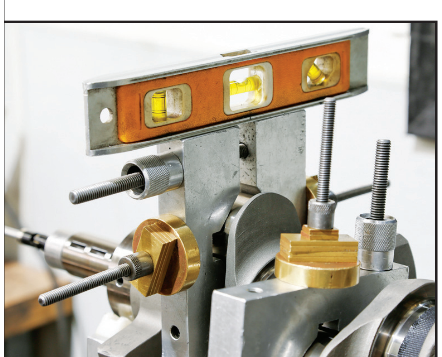




An extremely precise table scale, accurate to 0.5-gram, is used to measure the reciprocating and rotating hardware. Measuring the big end of a connecting rod determines its rotating mass, while measuring the small end determines its reciprocating mass. This is accomplished by using a fixture that allows weighing the big, and small ends of the rods separately.



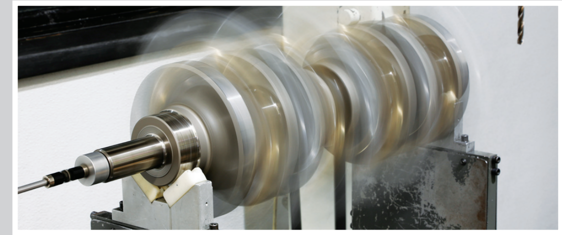
With all the measurements out of the way, the crankshaft is placed on the balancer stands, which can be varied in width to accommodate cranks of different lengths. A magnetic phaser assembly is then attached to the crank snout and checked for runout to ensure that it's centered. Balancing a crank requires adding or removing weight from very specific locations on the counterweights, and the phaser measures crankshaft rotation in degrees.



Aluminum bobweights are bolted to each rod journal to simulate the mass of the rods and pistons. The bobweights are equivalent to 100 percent of the rotating mass, and 50 percent of the reciprocating mass. The aluminum by itself is too light, so various combinations of brass weights are bolted to the aluminum bodies to establish the target bobweight. With the rod journal at 12-o' clock, the short edge of the bobweight must be perfectly level to ensure precise readings.

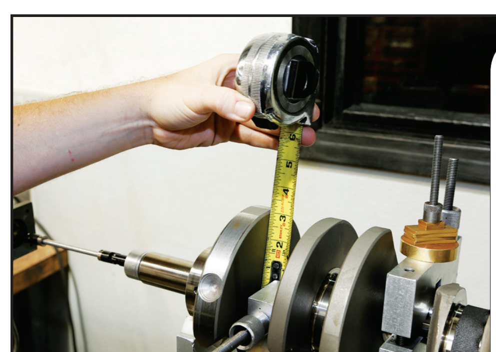
Before spinning up the crank, a series of measurements must be entered into the balancer computer to calibrate its sensitivity. First, the distance from the front stand to the center of the front counterweight is entered into the computer. Next, the distance from the front to rear stand is entered as well.

HOW GOOD IS GOOD ENOUGH?



A rotating assembly can be balanced to varying degrees of precision, and a moderate-rpm street motor can get away with far more imbalance than a high-rpm race motor. So how close is close enough? Since Americans don't subscribe to the metric system, the standard unit of measurement for crankshaft balancing is an ounce-inch. There are 28.34 grams in one ounce, so balancing to 0.5-ounce-inch means that a crank has roughly 14 grams of imbalance one inch from its centerline. "Many production domestic V-8s are balanced to around two ounce-inches while a 7,000-rpm street/strip performance engine is usually balanced to 0.75 ounce-inch," Judson explains. "A very high-end race motor will get balanced to 0.25 ounce-inch, which is seen as the holy grail of balancing by engine builders. Even at 0.25 ounce inch, the rotating assembly is still seven grams out of balance an inch from the crankshaft centerline. That might seem like a lot, but a 10,000 rpm NHRA Comp Eliminator motor will run all season long when balanced to 0.25 ounce-inch."

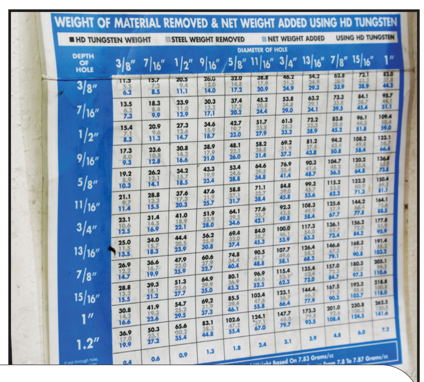
According to Judson, the distance from the crankshaft centerline to the edge of the counterweights is roughly three inches on most domestic V-8s. In the realm of balancing, this distance is called the correction radius. The problem is that not everyone factors in the dynamic effects of the correction radius when balancing a crank. "Many shops will balance a crank until the balancer reads 0.25 ounce-inch," Judson explains. "However, once you factor in a three-inch correction radius, the crank is actually 0.75 ounce-inch out of balance. So even though they think they balanced a crank to 0.25 ounce-inch, it's actually 0.75 ounce-inch out of balance. The reason you can get away with it is because a crank balanced to 0.75 ounce inch will run just fine in a typical street/strip motor, and it's still far better balanced than a production engine."



The correction radius is established by measuring from the crankshaft centerline to the edge of the counterweights, then entered into the computer. On this aftermarket small-block Windsor crank, the radius checked in a 3.125 inches, which is a very common figure for a domestic V-8. Machinists will often measure from the outside edge of the main journal to the edge of the counterweight, then use simple geometry formulas to calculate the distance from the journal edge to the crankshaft centerline. With cranks that have gun-drilled oiling holes in the center of the journals, the correction radius can be measured directly from the crank centerline.

Crank balancing equipment—such as the Sunnen DCB-750—measure the imbalance that exists in a rotating assembly in grams, but that's just half the story. "If you swung a rock tied to a string, then doubled the length of string and swung it again, the rock would pull on your hand twice as hard even though its mass hasn't changed. The same applies to a crankshaft, because the farther away a given unit of mass is from the crankshaft centerline, the greater effect it will have on the balance of the crank," Judson said. "As such, you can't just say that a crank is 60 grams out of balance. That would be like telling someone what time you want to meet them for lunch, without telling them which location you want to meet at. You have to specify both the mass of the imbalance and the distance of that imbalance from the crankshaft centerline. A crank that's 20 grams out of balance three inches from the crank centerline is the same as a crank that's 60 grams out of balance one inch from the crankshaft centerline." ■

After spinning the crank to 750 rpm, the balancer's computer indicates the imbalance measured in the counterweights. On this particular crank, 16.7 grams must be removed from the front (left) counterweight—and 11.8 grams from the rear (right) counterweight—to bring the crank into balance. The readout also specifies the location of the imbalance on the counterweight in crankshaft degrees. In this case, the imbalance on the front counterweight is located 32 degrees from TDC, while the rear counterweight imbalance is at 37.5 degrees.

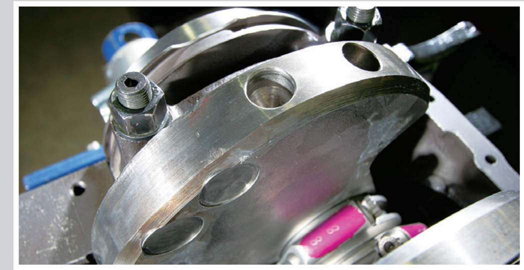


Machinists rely on a balancing chart that tells them the diameter and depth of hole that must be drilled into the counterweights to remove any given amount of mass. It also indicates the net weight that's added when pressing heavy metal (tungsten) into the crank.

Most balance jobs require removing mass from the crankshaft counterweights. However, power adder applications sometimes require adding mass to the crank in order to compensate for a heavy set of rods and pistons. Slugs of tungsten, also known as heavy-metal, weigh twice as much as steel and are pressed into the counterweights to add mass when necessary. Tungsten can be ordered in pre-cut slugs of any diameter and height, or in big sticks that can be cut down into multiple slugs. Tungsten slugs can also be turned down on a lathe to reduce their diameter.

Turning the crank by hand, the exact position of the imbalance can be located on the balancer computer. When drilling into the crank, it's preferable to use the largest drill size possible to save time and minimize the depth of the hole.

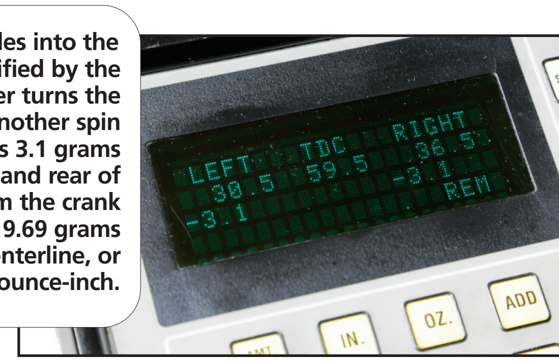
INTERNAL VS. EXTERNAL BALANCING



While an internally balanced crankshaft relies strictly on its own counterweights to achieve proper balance, an externally balanced crank relies on an additional set of counterweights integrated into the flywheel and harmonic damper. As such, the flywheel and harmonic damper must be bolted to the crank when externally balancing a rotating assembly. Generally, external balancing is less time consuming and costly than internal balancing. However, considering that the counterweights on a 12-inch diameter flywheel are located six inches from the crankshaft centerline, they impart far greater torsional loads on the crankshaft. These twisting forces can contribute to crankshaft flex while also compromising bearing longevity. Not surprisingly, external balancing is extremely uncommon in high-rpm race engines. Nevertheless, in a typical 7,000-rpm street engine, external balancing is plenty reliable enough to yield tens of thousands of miles of service.

When externally balancing a crank, holes can be drilled into the flywheel or damper counterweights to remove mass. If weight must be added to achieve proper balance, many aftermarket dampers come with several removable counterweights of varying mass that bolt into the inside face of the damper. Likewise, additional metal can be welded to the flywheel—or alternately—removing mass from the opposite side (180-degrees out) of the flywheel counterweight nets the same effect.

Adding tungsten to a crank involves drilling a 0.5 to 1.5-inch diameter hole, and pressing the slug into the hole with a .0015-inch interference fit. Some shops like to weld the slugs in place for extra security. The catch is that adding a 200-gram slug of tungsten requires removing 100 grams of steel with a drill, so the net weight gain is only 100 grams. If a crank that already has tungsten in it is rebalanced to a lighter set of rods and pistons, the tungsten can be removed and replaced with slugs of steel.



After drilling holes into the counterweights as specified by the drill chart, the balancer turns the crank over through another spin cycle. This time, it reveals 3.1 grams of imbalance at the front and rear of the crank, 3.125 inches from the crank centerline. This equates to 9.69 grams one inch from the crank centerline, or just a hair over 0.25 ounce-inch.

SOURCES

School of Automotive Machinists
samracing.com
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