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Engine Balancing: Shaky Notions

In automotive circles, it is axiomatic that good engine performance, vibration-free operation, and long bearing life are—to a small extent—the result of proper balancing of dynamic components during engine assembly. Offhand, one would think that the same is true for the Continental and Lycoming engines that power Cessnas and Pipers.

But is it? Does balancing make an engine better? Or, like the burning of incense during an outbreak of plague, are the benefits of engine balancing purely illusory?

These questions were brought into sharp focus for us by a recent letter from a reader in North Carolina (name withheld by request). Our reader, the owner of a 1958 Cessna 172, encountered numerous surprises in the course of rebuilding his plane's Continental O-300-A (with help from an A&P-rated friend). He writes:

"Here are some of the things we discovered about the 'precision made' engines we all fly behind. The crankshaft—undamaged by the prop strike that occasioned the teardown—was 17 grams out of balance. The heaviest connecting rod weighed 53 grams more than the lightest. The big-end-to-little-end weight varied by 25 grams. [On assembly] we sorted through dozens of rods before we found six that were close enough in weight to make them match. Four dozen valve springs were needed to find 12 that gave the same installed pressure. It went on like that for every critical part . . . Fully 88 percent of the PMA or factory parts we bought had to be returned because their tolerances were just too wide to make a suitable engine. Pistons? You wouldn't believe what we went through to get six that were just alike."

Our reader reports that after reassembly and run-in, his Skyhawk's engine seemed to give better performance (about 20 extra horsepower, based on cruise and rate-of-climb data), although it should be mentioned that other modifications were undertaken which could account for the changes. A new prop (with two inches more pitch) was put on the engine, for example, and an O-300-D camshaft was substituted for the original. Intake ports were specially ground, as well.

But the question remains: Shouldn't balanced parts make for a better, smoother running engine? And what about our reader's finding that critical parts, both factory-new and those removed from his engine, often varied significantly in weight?

We asked the shop manager of a well-known San Antonio repair station (one of the largest engine rebuilding shops in the U.S.) just how important engine balancing is in aircraft engines. "It's very important," he explained, "because you have forces that are of a reciprocal nature. If your parts aren't in balance, you'll wear out your main bearings, counterweights, cylinder walls, and everything else a lot faster. For that reason, we carefully balance each and every engine we build."

How carefully?

"Our pistons, many of which we make under our own PMA [Parts Manufacturer Approval], are held to plus or minus 1.77 grams; rods, usually one to two grams apart per pair, but four grams max; counterweights, our tolerance is two grams, but in practice it's more like a gram." (One ounce is equal to 28.3 grams.)

We asked the overhauler how these figures compared with Continental or Lycoming factory tolerances. His reply: "I was at a seminar recently where the Continental rep said that they don't even weigh reciprocating parts any more—they've decided it's not important. Counterweights, they still check, but not anything else. Lycoming is different. They hold their pistons to within a quarter-ounce, or seven grams; same with rods. Lycoming's crankshaft counterweights are held to two grams."

How balanced should engine parts be? *In a piston engine, maybe it doesn't really matter too much.*

The manufacturers' overhaul manuals are surprisingly casual on the subject of balancing. Lycoming, which sorts connecting rods into weight groups at manufacture, "recommends" in its manuals that mechanics choose rods from similar weight groups (i.e., similar P/N suffixes) when rebuilding engines; no other balancing recommendations are given. Continental, in its manuals, specifies a maximum weight variation for connecting rods of one-half ounce (14 grams) per pair in any given bay. (Note that the weight variation between bays is not specified; conceivably, two rods from different ends of the engine could be as much as several ounces apart—which is indeed what our reader found.)

The claim about Continental not balancing reciprocating parts at the factory appears to be true. We spoke with recently retired Continental vice president Carl Goulet on this subject—a subject we figured he should know well, having specialized in engine vibration analysis during his 27-year tenure with the Continental factory. He told *The Aviation Consumer*: "It's a fact, Continental doesn't pay any attention to balancing its pistons, or other reciprocating parts. But that's because it's absolutely unimportant."

Somewhat taken aback, we repeated to Goulet the statement made by the San Antonio overhauler that engine balancing is "very important," since engine imbalance could lead to rapid wear of bearings, counterweights, cylinder walls, etc.

"That's all bullshit," he replied. "In putting an engine together, you're concerned with *rotational* balance, yes. You are *not* concerned with *reciprocating* balance. Pistons are *reciprocating* parts: they move back and forth. If they're out of balance, it won't matter in the slightest, because the forces of combustion are much, much greater. On takeoff, in cylinder number one, when that cylinder fires you've got 15,000 or 16,000 pounds of combustion pressure pushing on that piston. At that moment—when piston number one is coming down on the combustion stroke—the opposite piston, piston number two, is riding up on the exhaust stroke. You've got unequal forces on opposite sides of the crankshaft. That's normal. But it's one heck of an unequal force—much more than any side load you could get from using unbalanced pistons."

According to Goulet, Continental at one point ran tests on an IO-520 that contained a piston that weighed *half a pound* more than its opposing mate. A complete vibrational analysis was performed. "And you know what?" pipes Goulet. "They couldn't even tell that the heavy piston was in there. There was absolutely no difference in the engine's vibrational characteristics."

As an aside, Goulet noted that "When you do run across an engine that has a vibrational problem of some sort, you *never* find that it's first-order." (The term "first-order" here refers to vibrations that peak in amplitude once with every crankshaft revolution.)

Asked why Superior, ECI, and other overhaul-parts suppliers make such a big deal out of their pistons being (supposedly) weight-matched to near-incredible tolerances, Goulet answered: "It's a sales ploy, that's all."

Is balance totally unimportant, then? "Rotational balance is certainly important," Goulet cautions. "You don't want a crankshaft to be out of balance, for example. The Continental factory dynamically balances all crankshafts twice: once before nitriding, and again before final assembly." According Goulet, one-half inch-ounce is a typical crank balancing benchmark.

We asked about connecting rods. "The heavy ends should, ideally, be pretty close in weight," Goulet points out, "because those ends travel with the crankshaft. You see, the rod is both a reciprocating *and* a rotational part: The crank end goes around in a circular motion and the piston-pin end goes back and forth." Goulet recommended placing the light end of a rod on a knife edge while weighing its heavy end. Paired rods should be heavy-end matched to within a quarter-ounce.

Pushrods, lifters, pistons, wrist pins, rings—all of these are unimportant from a balancing standpoint, according to Goulet.

Camshafts: "Camshafts aren't balanced at the factory, because the mass is so close to the axis of rotation."

"I'll tell you an interesting story about engine balancing," Goulet adds, a smile in his voice. "I ran into a fellow some years ago who said he had found a place that would completely balance his engine's parts for the nominal sum of $75. When he told me he intended to send his parts there for balancing, I frowned. 'You know,' I said, 'that's all a bunch of bull.' The man said 'Yeah, I know that.' Well, I asked him: 'If you know that, then why are you sending your parts out to be balanced?' 'Because,' he said, 'when I put that engine back in the airplane, I'll have a signed certificate guaranteeing the engine to be 100-percent balanced. That way, if anything ever happens with the engine, I'll have that piece of paper to prove that the pieces were all in balance when it went together. Also, when I go to sell the plane, there'll be that paper, proving that my engine was *immaculately, perfectly* balanced. Heck, I'd say that's $75 well spent, wouldn't you?' " —*KT*

A Little Help from the Insurance Commissioner

Got a problem with your aviation insurance? Your state insurance commissioner might be able to apply a little muscle to correct matters, especially when you get a helping hand from your insurance broker. When an Illinois pilot reached the age of 65 and was refused a renewal by his underwriter, his broker, Chuck Wenk of Wenk Aviation Insurance Agencies in Chicago, went to the state commissioner, and the underwriter was invited for a discussion of age discrimination.

The pilot had been insured by the company for 11 years without any type of claim on his Twin Comanche and had supplied a current EKG, biennial and second class medical.

Upshot: the underwriter renewed with no increase, and just renewed again on the pilot's 70th birthday.

While some state commissioners are described as ineffectual in correcting insurance problems, others are strong. Wisconsin, for example, recently created a stir by requiring plain-language policies. This caused some underwriters to leave Wisconsin till they get such policies, and others to hike prices to take advantage.

Navajo Flap Limit Relief

The Navajo flap-limits AD has been revised (as predicted in last month's SafeGuard) to provide relief to operators who wish to avoid the 25-degree flap restriction (15 degrees, for Cheyennes) required by AD 82-08-06. The new AD, No. 82-27-13, details an acceptable "alternate means of compliance" wherein existing 20:1 wing-flap transmissions can be reworked to a 40:1 gear ratio. This change, done in conjunction with a flap drive-shaft swap, eliminates the flap travel restriction of the earlier Airworthiness Directive.

But even when the shaft swap and gear-ratio changes have been made, Navajo operators will still have to abide by a new placard stating: "Operate flap control in small increments to assure flap symmetry. No flap selection with autopilot engaged."

Operators who do not incorporate the above modifications have until March 31 to install a Piper Flap Travel Restrictions Kit (P/N 764-396 or -397) as well as a Supplementary Kit (P/N 764-920L). The purpose of the Supplementary Kit is to provide additional travel stops to keep flaps from buckling in case of limit switch failure. The extra travel stops were cooked up by Piper last fall after an incident in which a Navajo Chieftain landed with its flaps grotesquely bent out of shape following a limit switch failure, which allowed the motor to continue to operate (thereby driving the flaps toward the 40-degree position after hitting the 25-degree center-rail stops).

Under the new AD, the additional travel stops are mandatory for Navajos that had previously incorporated Piper's P/N 764-396/397 flap travel restriction kits. (Installation of 40:1 transmissions obviates this requirement.)

Alas, a 100-hour repetitive flap transmission inspection required by the new AD is not "relievable" via any Piper service kit(s); chalk up one more lifetime AD for the Navajo.