OPINION |

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The bottom end

What's inside your engine's crankcase?

BY MIKE BUSCH

RECIPROCATING AIRCRAFT ENGINES COME in a variety of cylinder arrangements—radial, inline, V, and opposed—but most engines used in piston general aviation today are horizontally opposed four- and six-cylinder engines. These engines have two banks of cylinders directly opposite each other, with a single crankshaft between them. The crankshaft is enclosed in a crankcase, which also contains the camshaft, connecting rods, bearings, gears, and other components that are collectively referred to as "the bottom end" of the engine. It's bad news if something goes wrong with any of these bottom-end components, because it's necessary to remove the engine from the aircraft and "split the case" to gain access—and that gets expensive.

CRANKCASE

Think of the crankcase as the engine's rib cage. Besides supporting itself, the crankcase supports all the other components of the engine—internal ones such as the crankshaft and camshaft, and external ones such as the cylinders and engine-driven accessories. It must provide a liquid-tight enclosure for the lubricating oil that bathes the bottom-end components when the engine is running. It also incorporates provisions for attaching the powerplant to the airframe.

Crankcases are typically made of cast aluminum alloy that is both lightweight and strong. Strength is important because the crankcase is subject to tremendous reciprocating loads from the cylinders, as well as centrifugal and internal forces of the crankshaft's bending moments. The propeller also places thrust forces on the crankcase, and potentially severe centrifugal and gyroscopic twisting loads during abrupt maneuvering. The crankcase must be stiff enough to withstand all these loads without major deflection.

The case consists of two halves held together by a series of long through bolts that pass through both case halves just above and below the crankshaft, plus a series of short flange bolts that connect the top and bottom flanges. Each half of the crankcase contains transverse bearing supports, one for each main crankshaft bearing. These bearing supports add considerable strength and rigidity to the crankcase in addition to supporting the crankshaft and camshaft. The parting surfaces of the crankcase halves—both the bearing supports and the top and bottom flanges—must be machined perfectly flat to ensure that the case halves can be assembled in a structurally sound and liquid-tight fashion. These surfaces are in direct metal-to-metal contact, and have no gaskets to seal the parting seam.

The cylinders mount to external crankcase surfaces called pads or decks, which also must be perfectly flat. They must include a suitable means of fastening the cylinders to the crankcase. Each cylinder has a mounting flange secured to the deck by a combination of short threaded studs and long through bolts. Both Continental and Lycoming engines use a total of eight threaded fasteners—six studs and two through bolts—to attach each cylinder base flange to the crankcase deck. Each cylinder also has a skirt that extends a considerable distance inside the crankcase. Large cylinder-base O-rings provide a liquid-tight seal.

The crankcase incorporates mounting points for attaching the powerplant to the airframe. Most Continentals use a bed mount with four or six attachment points on the bottom of the case, while most Lycomings use a dynafocal mount with four attachment points on the rear of the case. These mounting points accommodate elastomeric shock mounts to absorb engine vibrations and prevent them from being transmitted to the airframe.

The crankshaft extends out of the crankcase both front and rear. The front of the crankshaft has the propeller mounting flange, and the rear of the crankshaft accommodates a large crankshaft gear that drives the camshaft and various other engine accessories.

A cast aluminum accessory case is bolted to the rear of the crankcase to enclose the engine's gear trains and to provide mounting pads for gear-driven accessories such as magnetos, pumps (fuel, oil, hydraulic, pneumatic), starter, alternator, tachometer drive or generator, propeller governor, and more. The gear ratios are designed to drive each component at the proper speed. For example, the camshaft turns at exactly one-half crankshaft speed, so the camshaft gear is twice the diameter—and has twice as many teeth—as the crankshaft gear that drives it. Magnetos in four-cylinder engines turn at crankshaft speed, but magnetos in six-cylinder engines turn at one and a half times crankshaft speed.

CRANKSHAFT

If the crankcase is the engine's rib cage, the crankshaft is its backbone. It's a massive hunk of chromium-nickel-molybdenum steel, forged for strength; machined and polished for smoothness; and case-hardened for durability. It's by far the costliest component of the engine—a new one could set you back $10,000 to $30,000.

The crankshaft's primary function is to transform the reciprocating motion of the pistons and connecting rods into rotational motion to drive the propeller. It's called a crankshaft because it's a shaft composed of multiple cranks (also known as throws) along its length—one per cylinder in horizontally opposed engines. These are formed by forging offsets into the shaft before it is machined. Each of these cranks is composed of a polished crankpin offset from the main axis of the crankshaft by a pair of cheeks.

The crankshaft is supported in the crankcase by the main bearing at each end, and between the throws. It has polished journals that mate with the main bearings. The main bearings and journals define the rotational axis of the crankshaft. The crankpins are offset from this axis by a distance that determines the stroke of the pistons.

The main journals and crankpins are bored hollow to reduce crankshaft weight, and nitrided (case-hardened) to provide a hard and long-wearing bearing surface. A diagonal oil passage running from each main journal to its adjacent crankpin provides lubrication to the crankpin from oil that is pumped into the main bearing.

The crankshaft is kept in balance by means of counterweights, which are simply extensions of the cheeks on the opposite side of the crankshaft from the throw. During manufacture or overhaul, the crankshaft is placed on knife edges, and small amounts of metal are removed from the cheeks until the shaft is in perfect balance.

Some crankshafts—notably those on six-cylinder engines—also incorporate movable counterweights called harmonic dampeners that help relieve the crankshaft of torsional stresses caused by the power pulses applied to the rearmost crankshaft throws, which are farthest from the propeller. These harmonic dampeners move and act as pendulums. The distance these pendulous counterweights

can move determines their resonant frequency, and this is carefully tuned to cause them to oscillate out of phase with the power pulses, thus absorbing some of the pulsatile energy and stress-relieving the crankshaft.

CAMSHAFT AND LIFTERS

The camshaft is responsible for operating the valves and controlling the timing of their openings and closings. It is gear-driven from the crankshaft with a 2-to-1 reduction gear train that causes it to rotate at one-half crankshaft speed. The camshaft typically has one cam lobe for each exhaust valve on each cylinder, and one double-wide cam lobe for each pair of intake valves on opposing cylinders. Thus, there are usually six cam lobes in a four-cylinder engine (four exhaust, two intake), and nine lobes in a six-cylinder engine (six exhaust, three intake). The cam lobes are highly polished and case-hardened (carburized) to provide a hard and durable wear surface.

Each cam lobe is carefully profiled to provide the necessary valve lift, duration, and timing. A cam follower—also referred to as a tappet or lifter—rides on the cam lobe and converts its profile into reciprocating motion that controls the opening and closing of the valve. Pushrods, rocker arms, and valve springs complete the valve train.

Horizontally opposed engines generally use hydraulic lifters that automatically compensate for any slop in the linkage, eliminating the need for valve train adjustments. Each contains a plunger, spring, and ball that cause the lifter to pump up with engine oil to the necessary length to achieve zero valve-train lash. The hydraulic lifters also supply engine oil through the hollow pushrods to provide lubrication to the rockers and cooling to the valves and springs.

Continental engines use barrel-style lifters that can be replaced easily, but most Lycomings use mushroom-style lifters which, unfortunately, can't be replaced without splitting the case. **AOPA**

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