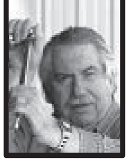


Some popular aircraft engine oils.

All About Oil

Part 1: What you should know

BY MIKE BUSCH

IF I ASKED YOU to explain the purpose of engine oil, you'd probably say something like "to lubricate moving parts and reduce friction and wear." That's correct, but lubrication is only one of six key functions that oil must perform in your piston aircraft engine. In fact, the lubrication needs of big displacement, slow-turning piston aircraft engines are really quite modest, compared to the high-revving engines in our automobiles. Lubrication demands tend to vary with the square of rpm, so a car engine has far more demanding lubrication requirements than an airplane's engine has.

Oil also serves as a vital coolant for engine components that can't be air-cooled. Pistons, for example, are exposed to just as much heat of combustion as cylinders, but they don't have cooling fins or exposure to airflow. The only thing that keeps them from melting is the large quantity of oil that is splashed and squirted onto the bottom of the pistons to carry away the heat.

Another key function of oil is to keep the engine clean. Compared to car engines, piston aircraft engines are positively filthy creatures. They burn heavily leaded fuel and allow large quantities of lead salts, carbon, sulfur, water, raw fuel, and other nasty combustion byproducts to blow by the rings and pollute the bottom end of the engine. The oil has to be able to keep these contaminants dispersed and hold them in suspension so they don't accumulate on internal engine parts in the form of sludge.

Oil also acts as a sealant to prevent the leakage of gases and liquids (including the oil itself) past piston rings, O-rings, gaskets, and various other kinds of seals.

If your airplane has a constant-speed propeller, oil serves as the hydraulic fluid used to adjust the blade pitch. If it is turbocharged, the wastegate is probably hydraulically actuated by oil as well.

Last, but certainly not least, oil is required to protect expensive components like crankshafts, camshafts, lifters, and cylinder barrels from rusting during periods when the airplane is not flown. Because we tend to fly our airplanes less often and more irregularly than we drive our cars, the preservative requirements of our aircraft engines are far more demanding than for automotive engines.

SIX KEY FUNCTIONS OF OIL

- Lubricate
- Cool
- Clean
- Seal
- Actuate
- Preserve

LUBRICATION

The purpose of lubrication is to reduce friction and wear on the engine's moving parts. Friction occurs because even the smoothest surfaces have microscopic peaks and valleys. Whenever surfaces come in contact, these

PHOTOGRAPHY BY **MIKE BUSCH**

tiny peaks adhere to one another via tiny "micro-welds." If those surfaces are in relative motion, the micro-welds constantly fracture and re-form, resulting in friction and wear.

There are several different kinds of lubrication. The most effective kind is hydrodynamic lubrication. It occurs when a fluid—most commonly a liquid like oil—is interposed between the moving parts. The relative motion of the parts creates sufficient pressure in the lubricant to keep the parts from touching. Think of a water-skier being supported by the skier's relative motion to the lake and the resulting pressure of the interposing water. The water pressure prevents the skier from sinking and contacting the lake bottom. Or consider a car hydroplaning on a rain-slicked road; its locked tires are separated from the pavement by water pressure—that's hydrodynamic lubrication.

This kind of lubrication works well if the relative speed of the parts is high enough to overcome the load pushing them together. If the relative speed is not high enough, then there will not be enough lubricant pressure to keep the parts separated. (Think of the towboat slowing down until the skier sinks.)

If hydrodynamic action cannot keep the parts separated, we must rely on boundary lubrication. Boundary lubrication relies on a thin, soft, solid film deposited on the moving parts—typically by chemicals called "extreme pressure additives." That thin film reduces friction and wear by chemically interfering with micro-weld formation.

Rub your hands together vigorously and you'll feel the friction between your palms in the form of heat and resistance to movement. You just created and then fractured a few zillion micro-welds on the surface of your palms! You can reduce the friction in several ways—for instance, by coating your palms with Vaseline or by dusting them with talcum powder. Think of the Vaseline as hydrodynamic lubrication and the talc as boundary lubrication.

Friction and wear are caused by the fracturing of "micro-welds" between moving surfaces.

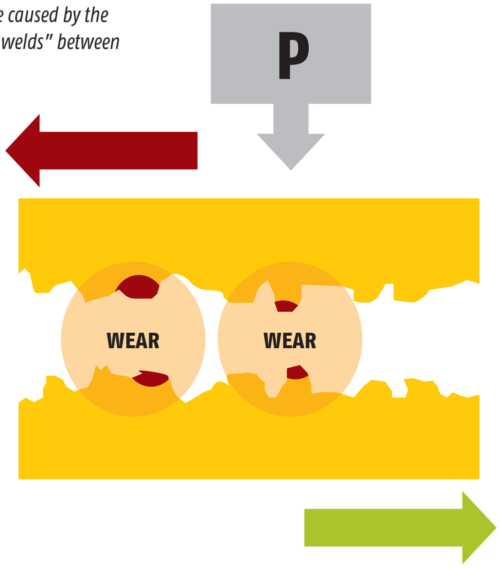
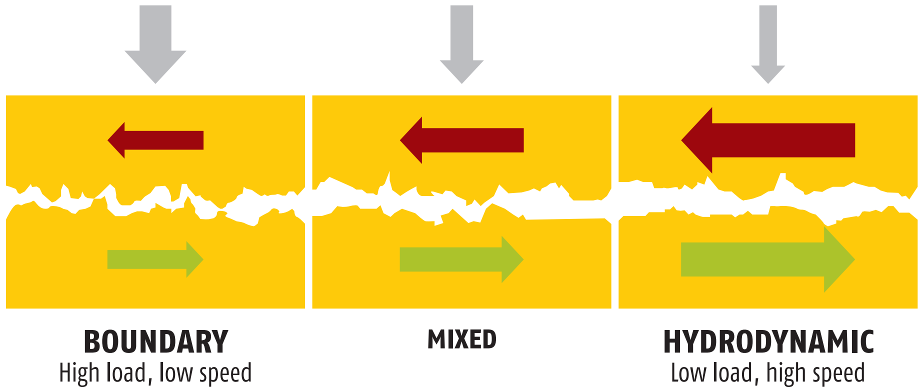


DIAGRAM BY **MIKE BUSCH**



Hydrodynamic versus boundary lubrication.

TYPES OF LUBRICATION

Most of the lubrication in our engines is hydrodynamic. It's accomplished in two different ways. Some moving parts—such as the main and rod bearings—are pressure lubricated by oil that is distributed directly to those parts by means of a series of drilled passages in the crankcase and crankshaft known as oil galleries.

Many other moving parts—pistons, rings, cylinder barrels, cam lobes, lifter faces, gears—receive no direct lubrication from oil pressure. These critical components rely entirely on splash lubrication. When the engine is running, lots of oil extrudes from the crankshaft's pressure-lubricated main and rod bearings and is flung in all directions by the rapidly turning crankshaft, splashing oil on everything in the vicinity.

Other critical parts are too slow moving and too heavily loaded to be separated hydrodynamically and rely mostly on boundary lubrication. One interesting example is the interface between the piston rings and cylinder barrels. Most of the time the piston is moving rapidly inside the cylinder and the ring-to-barrel interface is lubricated hydrodynamically so there's no metal-to-metal contact. At top-dead-center, however, the piston slows to a complete stop, then reverses direction. The slowing of the piston defeats any effective hydrodynamic lubrication in the critical ring-reversal area at the top of the stroke. For a brief but critical period during each crankshaft rotation, the rings stop moving, sink through the oil film—like a water-skier whose towboat stopped—and come in contact with the cylinder walls. The only thing that protects this "ring reversal area" from accelerated wear is boundary lubrication.

Boundary lubrication is also crucial during the first few seconds after the engine is started. That's especially true if the aircraft hasn't flown for a while and most of the oil has stripped off the parts. Until oil pressure stabilizes and the crankcase fills with splash oil, dry engine parts have to rely on boundary lubrication alone.

TYPES OF ENGINE OIL

Now let's talk about the different types of oil, and the pros and cons of each. Here are the six most widely used piston aircraft engine oils in the United States:

- Multigrade Oils:
  - AeroShell 15W-50 (50 percent synthetic)
  - Exxon Elite 20W-50 (25 percent synthetic)
  - Phillips X/C 20W-50 (0 percent synthetic)
- Monograde Oils:
  - AeroShell 100/80 (non-ash dispersant break-in oil)
  - AeroShell W100/W80 (0 percent synthetic)
  - AeroShell W100 Plus/W80 Plus (0 percent synthetic)

DIAGRAM BY MIKE BUSCH

Many other moving parts—pistons, rings, cylinder barrels, cam lobes, lifter faces, gears—receive no direct lubrication from oil pressure.

AeroShell 15W-50 is by far the most popular multigrade oil. It is referred to as a semi-synthetic oil because it is a 50-50 hybrid of petroleum-based mineral oil and a synthetic oil called polyalphaolefin or PAO. To this half-and-half mixture of mineral and synthetic base stock, Shell adds chemicals called "viscosity index improvers" to give the oil its multigrade properties. It also adds a complex additive package including ashless dispersants to help prevent sludge, corrosion inhibitors to help prevent rust, and an extreme-pressure boundary lubricant called butylated triphenyl phosphate (bTPP).

Exxon Elite 20W-50 is a very similar formulation to AeroShell 15W-50, except that its base stock is only 25 percent synthetic and 75 percent petroleum-based. Its additive package is nearly identical to the one used in AeroShell 15W-50.

Phillips X/C 20W-50 is an inexpensive, no-frills, all-petroleum multigrade. It's made strictly from dead dinosaurs with no synthetics. Phillips adds viscosity index improvers to obtain multigrade properties, and ashless dispersants to prevent sludge.

Moving on to the monograde oils, AeroShell straight 100 is an SAE 50 mineral oil with minimal additives. It's used primarily as a break-in oil, and occasionally as an operating oil for radial engines.

AeroShell W100 is by far the most popular monograde oil. The "100" means that its viscosity rating is SAE 50, and the "W" prefix means that it contains an ashless dispersant additive package to help keep particulates in suspension and minimize sludge formation. (This "W" prefix that denotes ash dispersant additives should not be confused with the "W" suffix in "15W-50," which denotes that SAE 15 is the oil's winter rating.)

AeroShell W80 is a less-viscous version of AeroShell W100, and it's used as a wintertime oil by operators who prefer monogrades.

AeroShell W100 Plus is simply AeroShell W100 to which Shell has added the same package of

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anticorrosion and antiscuff additives that it uses in 15W-50.

MONOGRADE OIL VERSUS MULTIGRADE OIL

Monograde oil is simply mineral oil plus an additive package. It has viscosity, or thickness, that varies rather dramatically with temperature. At operating temperature—around 200°F—it's quite thin and flows very freely. But at room temperature, it's thick and gooey. Get it cold enough and it won't pour at all.

Multigrade oils are much less thick and gooey at cool temperatures. They still get thicker as temperature decreases, just not nearly as much. To make a multigrade oil, you start with a really thin monograde oil (something like SAE 10 or 15) and then add an artificial thickening agent called a "viscosity index improver" (VII). This is a man-made polymer that has the unusual property of getting thicker and more viscous when heated—precisely the opposite of what mineral oil does. By combining oil with VIIs, the manufacturer can obtain pretty much any viscosity-to-temperature curve it likes. Multigrade aircraft oils are roughly 90 percent base stock, with the remaining 10 percent composed of VIIs and other additives.

At operating temperature, AeroShell W100 and 15W-50 have essentially the same viscosity. At room temperature or colder, the difference in viscosity is obvious and dramatic. The W100 pours like blackstrap molasses, while the 15W-50 pours like Aunt Jemima Lite.

The advantage of multigrade oil is that it doesn't thicken nearly as much at cold temperatures. This offers a significant benefit during cold weather if you have to start without a preheat. With multigrade oil, the oil flows more quickly to the main and rod bearings, and splashes more quickly onto the cam, lifters, pistons, and cylinders.

On the other hand, the fact that multigrade oil remains thin and pourable at cool temperatures also can mean that it drains off engine parts more quickly after shutdown. You can see this for yourself by checking how much longer it takes for the oil level on the dipstick to stabilize after shutdown. It takes many, many hours with a thick monograde oil like AeroShell W100, but less with a multigrade like 15W-50. Consequently, multigrade doesn't provide as long-lasting a physical barrier against corrosive attack during extended periods of disuse. This is not important for "working airplanes" that fly every day or two, but it can be important for airplanes that fly irregularly and sometimes sit for weeks at a time.

MINERAL OIL VERSUS SYNTHETIC OIL

Oil is made up of giant molecules called polymers. Some are natural like mineral oil, others man-made like PAO. Different polymers have different shapes. The molecules of mineral oil have a lot of side branches, while the molecules of synthetic oil are smoother and less "branchy."

Mineral oil gradually degrades the longer it remains in service. The little branches gradually shear off the molecules—known as polymer shearing—which causes viscosity to decrease. Because synthetic oil is less branchy, it suffers far less from polymer shearing and retains its viscosity longer. This means that synthetic oil can go a lot longer between oil changes, at least in automotive applications.

The smooth, less branchy molecules of synthetic oils like PAO do offer some significant advantages over mineral oil. They provide improved lubricity, simply because they are smoother and more slippery. They also last longer, because they suffer less from polymer shearing and thermal breakdown.

But mineral oil also has its advantages. Its branchy molecules do a much better job of holding particulate contaminants in suspension so that they can be drained out at the next oil change instead of settling out as sludge. In fact, the full-synthetic Mobil AV 1 was withdrawn from the market more than a decade ago because so many engines were ruined by lead sludge deposits. To put it bluntly, synthetic oil simply can't deal with filth.

Mineral oil is also a better sealant, because its branchy molecules are less likely to sneak by O-rings and gaskets in the form of oil leaks.

The advantages of synthetic oils—which are quite compelling for automotive and turbine use—are much less significant for piston aircraft engines. The improved lubricity is less important simply because piston aircraft engines have such modest lubrication requirements. The extended oil-change intervals that synthetics offer in automotive applications are of little use in piston aircraft engines because the oil gets so filthy with blowby that it's a bad idea to go more than 50 hours without draining the dirty oil.

Corrosion is the No. 1 reason that piston aircraft engines fail to make TBO (time between overhauls). We almost never wear these engines out; we rust them out. This is a big problem in the owner-flown fleet, because owner-flown airplanes tend to fly irregularly. Working airplanes that fly every day or two almost always make TBO without breaking a sweat.

I personally prefer mineral oils over semi-synthetics for piston aircraft engines. The advantages of synthetics simply don't benefit these engines the way they do automotive and turbine engines. I also prefer monogrades over multigrades, except when multigrade is necessitated by exposure to unpreheated cold-starts in sub-freezing temperatures. For aircraft operating in cold climates, I recommend using a mineral-based multigrade like Phillips X/C 20W-50 during the four coldest months of the year, and switching to a monograde like AeroShell W100 for the remaining eight months for maximum corrosion protection. Of course, if the airplane flies frequently and regularly so that corrosion risk is low, then there's nothing wrong with using a multigrade year-round.

Next month we'll cover additives, oil consumption, oil level, oil-change interval, oil filter inspection, and laboratory oil analysis. *EAA*

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