Imports Aloft!

Into the Wild Blue Yonder!

Automotive engines are much more powerful for their weight and much more reliable than ever. So here's the acid test, where they absolutely have to be reliable. And turn out to be just that.

Some people find import engines really uplifting — so much, they've built airplanes around them. It may seem surprising a small car engine can produce enough power with enough reliability to keep an aircraft moving and aloft, but that's just what hundreds, perhaps thousands of homebuilding aviators have found with their auto-to-aero engines, originally and terrestrially from Volkswagen or Subaru (because of the aircraft-like configuration), from Mazda/Wankel, Suzuki, Honda and even Chevrolet (an import? Well, sort of. Wasn't Gaston Chevrolet himself Belgian?).

Last August, to find out more, Karl Seyfert, redoubtable editor of this fine publication, and yours-truly, humble technoscribbler, tore ourselves from the heady delights of Akron, Ohio, to attend the Experimental Aircraft Association's annual AirVenture at Oshkosh, Wisconsin, for one week each year the busiest airport in the world. The EAA is an organization of several hundred thousand people interested in building their own aircraft, restoring classics or military airplanes and all things aviatory. The group's name derives from the legal category *experimental*, a category into which all homebuilt aircraft fall. Strictly that means not officially type-certified, rather than focused primarily on basic aeronautical research, though there were many innovative designs at Oshkosh along with the more traditional homebuilts.

Using car engines in aircraft is not something particularly new. In a way, bicycle mechanics Orville and Wilbur Wright were the first aircraft homebuilders, though they cast and bored their own engine from scratch rather than filching one from a pre-1903 horseless carriage. In 1928, another mechanic, Bernie Pietenpol, built his first "Air Camper," one of the oldest designs for car-powered homebuilt aircraft still flying, in fact, still being built 'new' today. The 'Piet' originally used a Ford Model T engine, a powerplant readily available at the time. Sporting perhaps 35 or 40 horsepower, the Model T's inline-four, dense, black and massive, tipped the scales at over 350 pounds of Detroit Wondermetal, not yet counting its radiator and coolant hoses. That made it far from the power-to-weight equal of even the least advanced modern engine, but it could still tractor the Pietenpol through the air fast enough to keep it up (There's an old pilot's commandment: *Maintain thine airspeed, lest the earth rise up and smite thee*), or keep it up at least as long as the Model T kept clicking steadily over and the pilot stayed reasonably heads-up. A number of Model-T-powered Pietenpols are still flying, licensed and airworthy if not blisteringly fast. The 'updated, modern' *[sic]* version of the Air Camper uses a Corvair engine. *Ah-ooh-gah!*

Let's see what's involved using a modern car engine in a homemade aircraft and why people choose the particular engines they do. While some people go for very exotic conversions, like transforming turbochargers into turbojets, for now let's stay with plain-vanilla four-cycle engines.

Why Fly Automotive?

The major reason for using a car engine in a homebuilt airplane is, of course, cost. Even if you pay top dollar for a new automotive engine or buy one specifically converted for aircraft by one of the companies specializing in auto-aero work, you don't come close to the price of the least expensive certified aircraft engine. And if you want to build, for instance, a one-to-one scale P-51 Mustang, that hefty tag on the aluminum-block 454 may seem like pocket change compared to what you'd pay for an authentic fire-breathing Allison V12.

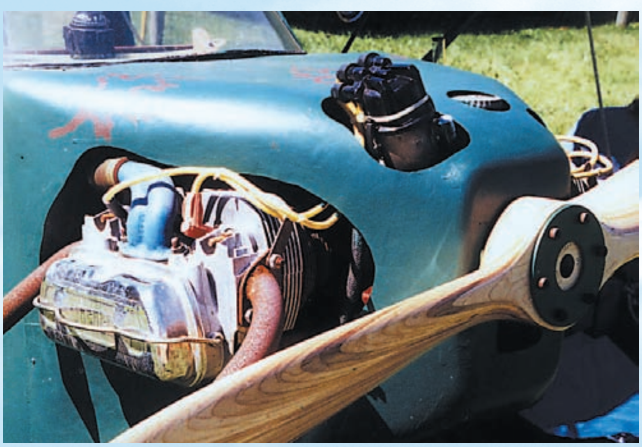
Aircraft engines are expensive for two reasons: the designs emphasize reliability over economy (no argument there), and they just don't build them in big numbers. There are about 10,000 new cars and trucks built each year for every new single-engined, private plane. I still remember the answer to someone's question at a past GM press conference, Why are you still making the Iron Duke? "Six-hundred bucks apiece. In the car. Running." You can spend more than that for a radio-controlled model plane's engine. While the wheezing, porky old Iron Dukes are rare or nonexistent in homebuilt aircraft, the other engines mentioned earlier are not, having power-to-weight ratios comparable to and sometimes superior to certified aircraft engines, at a fraction of the cost.

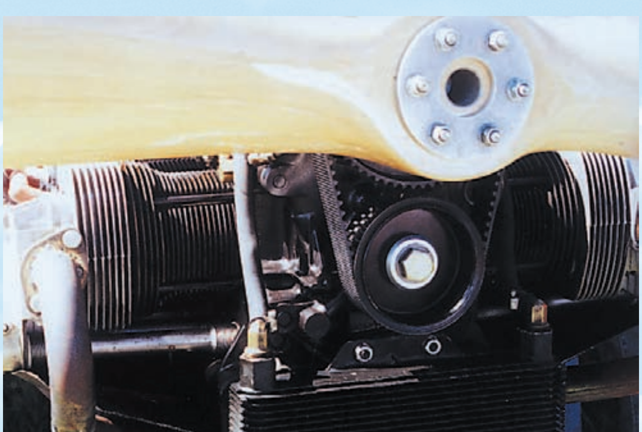
But *'Cost'* at What Cost?

But what about reliability? Aircraft engines are reliable for three reasons: the basic simple design, the low compression ratios (and consequent understress) and the redundant ignition systems. By design, they are 'time-tested' pushrod boxer engines, with everything gear-driven. "Simplicate and add lightness." An aircraft powerplant will stun an experienced automotive mechanic with its simplicity – you'll look it over and, immediately recognizing what everything does, wish cars were more like that. Every nut and bolt of any importance is safety-wired, just as we lock castellated fasteners for steering and suspension with cotter pins.

Aircraft engine pistons are almost twice the diameter of car engines with the same horsepower. The displacement difference allows the smaller engine to turn faster and produce the same output, but requires gear reduction to achieve the relatively low propeller speeds the aircraft engine handles direct-drive.

Put a Holley on that VeeDub, and it'll fly! Really! The classic auto-to-aero engine is the VW flat-four, from its numbers, from its air-cooling and from its configuration, similar to standard aircraft engines. While some aircraft homebuilders just bolt a propeller to a flange welded to the front of the VW crankshaft, others have used toothed-belt reduction drives or gears to allow the use of larger, more efficient propellers and higher, more powerful engine speeds.





Compression ratios are six or seven to one, far lower than a modern car engine's. A *good* result on an aircraft engine compression test is 80 psi, which would just about be a dead hole on a car engine. Wide-open throttle at six-to-one translates into about half the peak pressure it would at twelve-to-one, and the mechanical stresses correspond.

Aircraft ignition is by dual-magneto/dual-spark, essentially the same spark generator system rope-start lawnmowers use a single one of, but with more durable design and materials. The reliability comes not from the magneto, but from the second magneto — with two entirely redundant and independent ignition systems from the primary grounds to the dual spark plugs, the chances of both failing at once are acceptably low. Ignition timing for the magnetos, you might find interesting, is fixed at about 25 BTDC and two or three degrees apart (so you can hear a slight rpm difference when, as a pre-flight test, you sequentially disable first one and then the other). Why? Because of the flip-side of Murphy's Law: If a spark advance isn't there, it can't fail. No flyweights, no springs, no pivots, no vacuum diaphragms, no knock sensor, no microprocessor spark map. In a near-constant-speed engine, you can get the effect of ignition timing by controlling carburetor mixture. A rich mixture burns faster than a lean mixture, and you can manually adjust the fuel/air ratio at all speeds with most aircraft carburetors.

But automotive ignition has improved dramatically, too, since the days when people towed their dead cars in every fall for 'tune-ups' ("… whether it needs it or not!"). You can't just snip out an engine management system whole-hog and crimp its harness into an airplane because the car system focuses primarily on emissions performance rather than power and range, i.e., safety. You can use much from automotive solid-state spark and fuel systems, but you have to know to disable such things as safeguards that shut down an overheating engine – in an airplane you might be quite happy to toast an expensive block for another two minutes' power. Besides, there are providers of redundant (dual) transistorized ignition systems for auto-aero conversions. A few hardy souls even use automotive Diesel engines for aircraft, solving by elimination both the problems of ignition reliability and of mixture control, as well as making jet fuel an available motion-lotion.

Prop Puzzles

With the reliability question answered, there are several other technical challenges. An aircraft engine runs at a speed far steadier than a car engine, a speed limited by the aerodynamics of a propeller: As the propeller turns, it slices a helical disk through the air, a disc through which it pulls air and through which it pulls itself and the airplane.

One of the more unusual engines in homebuilt aircraft is the three-cylinder Suzuki engine. There have even been cases where a builder ties two 'Zuk engines together to drive the same propeller.

The torque of the engine changes through the propeller into the thrust of the propeller disc. Generally speaking, the lower the average load per square foot of propeller disc area, the more efficient the propeller. What that means in practical terms is that you want a large, slow-turning propeller to get the best, most efficient conversion of engine torque into propeller thrust. There are limits, of course. The propeller has to clear the ground during takeoffs and landings; it can't be too heavy to lift or too expensive to build or buy. The propeller can't be so large or turn so fast the tips approach the speed of sound, either. At that speed, air starts to compress and torque requirements go off the scale. So a tiny propeller, however speedy, can't generate enough thrust, while a propeller eight feet across is sonic-boom tip-limited to about 2400 rpm.

Aircraft engine manufacturers, sensibly enough, build engines to torque-peak at 2200-2400 and redline at about 2750. You see the rpm/volumetric efficiency problem right away: Car engines reach their peak performance and efficiency at double to triple that speed.

There are two solutions: Live with the lower speed and torque; drive one-to-one direct from the crankshaft. Or wind the engine up and rig some kind of rpm reduction. Either way, other things being equal, two engines burning fuel at the same rate will produce the same power, either at low speed with 'cubes' or at high speed with rpm.

When 'Push' Comes To 'Shove'

But, Houston, we have another problem. The propeller slices a helical thread through the air and pulls with several hundred pounds tension on its hub. The hub bolts to the crankshaft, and passes this tension along directly. The crankshaft passes this tension to the block through the thrust bearing. Oops! There's our problem. The only mechanical friction here is at the thrust bearing. It's like driving with several hundred pounds tension or pressure constantly against the crankshaft: Before long you'll have axial play, and not long after that you'll snap connecting rods with a sudden change of throttle and load.

We could plagiarize from the traditional aircraft engines; they use an enormous thrust bearing with additional lubrication passages. But that's much more difficult than it sounds, sort of like adding one more cylinder to an engine – could be done, but….

People often use VW flat-fours in direct-drive, sometimes sawing the engine in half to make a flat-two for very light aircraft. This is not too surprising since the VW flat-four is a fairly old, low-speed design, with the cam in the block popping the valves through pushrods, as traditional aircraft engines do. The VW also has an enormous thrust bearing, and not much torque or thrust at direct-drive speeds.

Like the VW flat-four, the Subaru pancake engines have the same shape as most aircraft engines. Besides that, the Sube also can produce substantially greater power if used with a reduction gear and turbocharging. And like the VW, the Sube pancake ticks over very smoothly. Both the comparatively rare flat-six and the more ordinary flat-four find their way into aircraft.

Virtually every other automotive engine used in homebuilts has either a reduction gear (fixed-ring/crankshaft-sun/output-planetary) or a toothed belt reduction drive like a timing belt. Cautiously enough, as you can see in the photo, most homebuilders going this latter route use redundant toothed belts. An interesting technical tidbit: With such speed reduction, you never use an integral reduction ratio, like two or three to one. That could set up resonances and destructive vibration among the engine pulses, the propeller blades and the wings. High rpm engines, like Hondas or RX7 Wankel rotaries, *always* use a reduction drive. One Wankel conversion, capitalizing on the smoothness and small size of the Mazda rotary engine, is a sideline product of an *Import Service* automotive regular, Atkins Rotary Specialties (**Circle Number 125** for more information from them).

A reduction unit, gear or belt, also lets the builder easily solve the thrust-bearing problem I mentioned. With a gear or toothed-belt reduction drive you can use tapered or ball bearings to control the thrust forces.

Buried in all the ducting is a Mazda rotary engine, spinning with less vibration than anything else burning gasoline in combustion chambers. Mazda engines have proven themselves very dependable in racing, so their employment in homebuilt aircraft is a natural extension of their appeal, not least of all because they'll fit in a very small space.

Aircraft carburetors are much simpler than automotive, but much more expensive. One solution used by this homebuilder is the use of Bing carburetors from a BMW motorcycle.

Bad Vibes

Vibration in a car is annoying and a symptom of something out of balance. It's more serious in an aircraft. A light aircraft's engine is much heavier in proportion to its total weight than a car's, even if we're talking about the same engine in both. What's more, the engine often runs at full or nearly full power. Most homebuilt aircraft weigh substantially less than 1000 pounds, a third to half of it the engine and contraptions it needs (like gasoline lines, pumps and tanks). That means engine vibration looms larger in the scheme of things aero-vehicular and can cause premature metal fatigue. It also explains some of the engine choices: Flat-fours are amazingly well balanced, as are inline fours when they're small or countershaft-balanced. Inline sixes are perfectly smooth, but inherently heavy for their displacement. V6's are inherently vibratory, unless they include a balance shaft, and then they're heavy. The smoothest of all, of course, is the Mazda/Wankel. That engine, as people who work on them regularly can attest, is almost as vibration-free as an electric motor. It's the only automotive engine I've ever seen running on a table, completely unattached except by coolant and fuel lines. There's a good deal of debate, as you surely know, about just how fuel efficient or inefficient the engine is, but we didn't learn anything to settle that question.

Triangulated Alignment

Engine mounts in cars are pretty boring. They keep the engine from twisting away from its output torque and cushion its connection to the frame, unibody or subframe. In an airplane, they have more to do. Not only do they keep the engine connected to the fuselage and above the runway, they control the geometry between the propeller disk and the airplane. In other words, they're much like front-end alignment, as well as mechanical support and vibration dampers. Both the weld dimensions and quality are absolutely critical, because if the engine falls out of the aircraft, the plane suddenly becomes very tail heavy and uncontrollable. Many homebuilders take the path of discretion rather than valor and hire an experienced aircraft welder to make their mounts or buy some ready-made. Aircraft engine mounts are often made from strong and light 4130 steel tubing.

Is this an interesting recreational way to apply your mechanical skills? It strikes me that it compares favorably to motorsports. After all, how many cars can manage three or four G turns, never mind cross-country trips at 150 mph or rolls and loops? In certain important ways an aircraft is simpler than a car, though if you make a mistake with one, it's likely to be a doozie. However, a great deal of help is available through the EAA and other sources, so if you're interested in joining the scarf-and-goggles gang, **Circle Number 126** on the Reader Service Card, and we'll pass your name along to them. This year's EAA AirVenture runs from July 24th to August 1st. ■

— By Joe Woods