Stroker Big-Bore Engines

How Big Can It Go?

BY STEVE WHITSON

POWER EQUALS SPEED and performance. There's no doubt about that. So how do you get that power, given what's available on the market? There are many options: turbocharging, turbine engines and modifications of the existing engines. These methods have their benefits and pitfalls. But there's no free lunch; if you want this, you also get that.

The Basics

Let's cover the basics before we get to modifications. Most of our aircraft have internal-combustion, constant-volume heat engines. An external-combustion engine has external boilers and heat exchangers, like the steam engine. Gas volume increases with the application of heat, and heat engines produce power from this expansion of gases.

Additionally, a heat engine requires both a heat source and a cold sink (i.e., the heat source must be hotter than the exhaust gases). The thermodynamic efficiency of the engine is defined by the difference between these two.

A Few Definitions

Compression ratio is the difference between the volume of the cylinder when the piston is at the bottom of the stroke and when it's at the top. Compression ratios in aircraft engines range from about 6 to 1 to as high as 10 to 1. Stroke is the distance the piston travels inside the cylinder. The longer the stroke, the more volume in the cylinder. Bore is the diameter of the cylinder. The larger the bore, the more volume in the cylinder. Engine displacement is the volume of the cylinder times the number of cylinders. This is usually indicated in cubic inches. For example, the Lycoming IO-540 has a displacement of about 540 cubic inches.

To ignite the fuel/air mixture, there's either spark or compression ignition. Compression ignition is how a diesel works. Most of us have engines that use spark plugs. Spark plugs restrict the compression ratio of the cylinders because of detonation. Diesels don't have that problem because the fuel is injected at the optimum moment, therefore they can have high compression ratios.

The fuel/air mixture ratios range from about 20:1 to 8:1, and they're controlled by a carburetor or a fuel-injection system. The theoretical ideal, where all the fuel is used, is called the stoichiometric reaction, and it's at 15:1. Carburetors use a venturi to restrict airflow, which increases the velocity of the air. In turn, this decreases the pressure at the venturi neck. This decrease in pressure draws in fuel through the jets. Fuel injection uses pumps and lines to inject fuel directly into the induction system at the intake valve.

Some Math

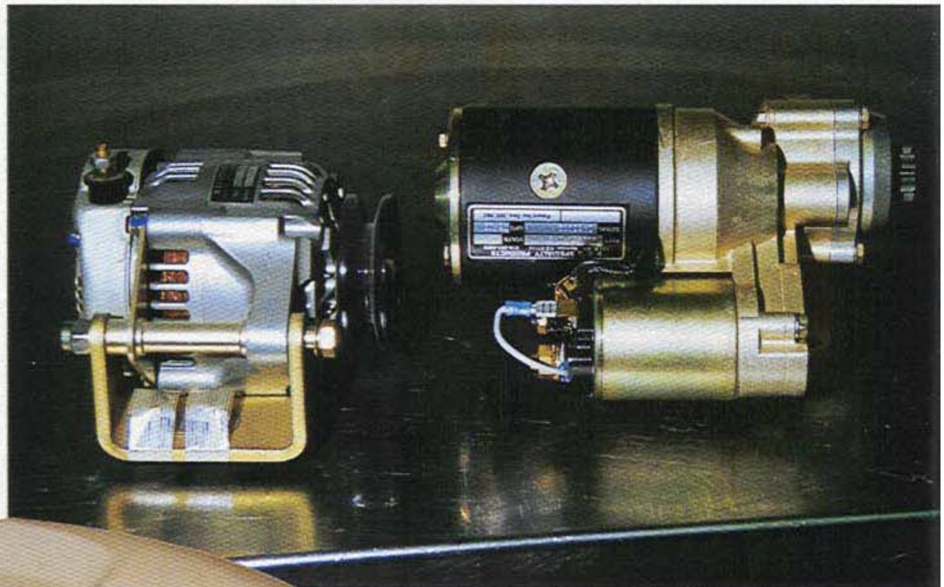
Stroke, as already defined, is the length the piston travels in the cylinder. Stroking an engine is an old racing term for increasing the distance the piston travels. The displacement of an engine can be figured by using

The stroke is lengthened by reducing the size of the rod journals without touching the part of the circumference farthest from the crank's longitudinal centerline.

the following formula: Displacement is = to N x Pi x $B^2 \div 4$.) Where N is the number of cylinders, B is the bore, S is the stroke and Pi is 3.1416. You can see that increasing either bore or stroke will increase the displacement.

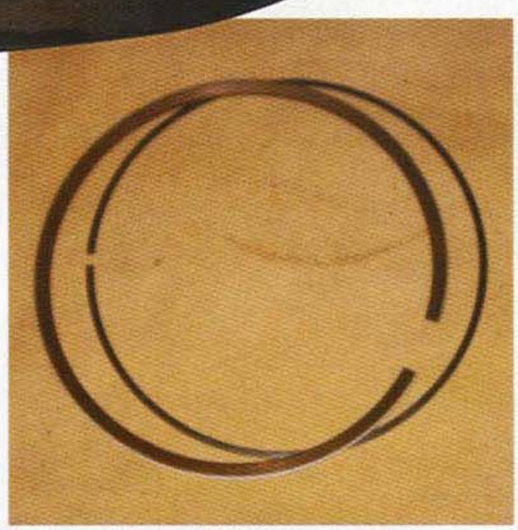
This is directly translatable to horsepower, as seen in the equation for indicated horsepower: Indicated Horsepower = P*L*A*N*K ÷ by 33,000. P is the mean effective pressure in psi, L is the stroke in feet, A is the cylinder area in square inches, N is the power strokes per minute (rpm/2) and K is the number of cylinders. So the longer the stroke and/or the bigger the bore, the more ponies spinning the prop.

I recommend you purchase the *Sky Ranch Engineering Manual* by John Schwaner. This book is an excellent source of engineering, technical and practical facts that cover the gamut of aviation piston engines. It's 500 pages and costs $19.95, plus shipping.



The lightweight starter and alternator will keep the performance up and the weight down.

The pistons are custom made for a 10:1 compression ratio. They have a ceramic coating on top for heat resistance and a P2 Moly coating on the skirt for abrasion resistance.



Another innovation is the use of gapless piston rings. The larger ring has a step cut in it so the smaller ring can sit in the step and in the same groove.

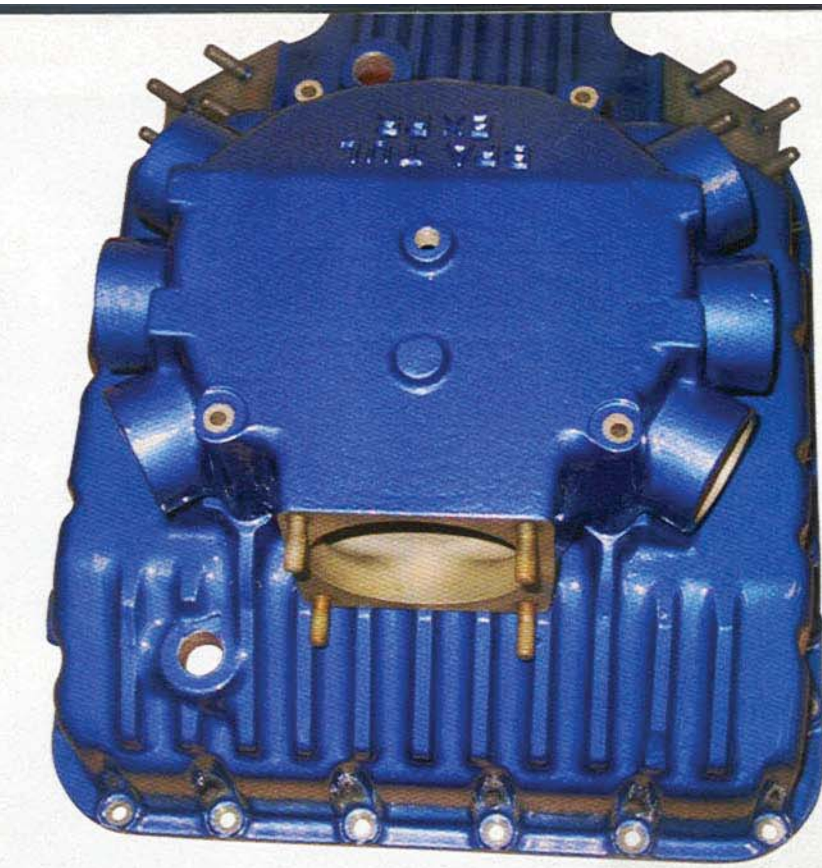
Modifications

To achieve more power from the basic engine, aircraft engine builders have been listening to their counterparts in the racing industry. This quest for power comes down to: increasing the volume of the engine, increasing the compression ratio, forcing more of the fuel/air mixture into the cylinder, burning the mixture more completely and exhausting the spent gases more efficiently.

There's nothing new to any of this, and the mechanics and engineers have been pursuing these goals since the first engine was developed. The biggest obstacle in their path has been reliability. Anyone who has watched drag-racing events has seen the effects of overdoing the engine modifications. These spectacular engine blowups, followed by flying debris and fire, aren't a good thing—especially in flight. So those involved in the aviation power industry must temper their desire for power with the needs for safety and the preservation of life—the engine's and the occupant's.

We also spoke with Jack Simmons, a builder and modifier of motorcycle engines for the race circuit. He builds stroker engines also but has other concerns due to the abuse racing puts on the parts. He said stroking primarily increases the engine's displacement, but it also adds more torque. The low-end torque comes from the longer stroke, where the fuel has more time to burn and push on the piston and the increased piston speed in the cylinder at the same rpm. Again, there was the admonition that there was only so much that could be done before the engine would be disabled.

But there are things that can be done. And when we heard about a stroker engine being built by the fellows at an adjacent airport, we went to see it for ourselves. Remember, there's a price for everything. More horsepower means more heat and more stress on all the internal parts. As John Schwaner said in a short interview, there's a point in the normal aircraft engine where the counterbalances just won't work. Where that point is, and what happens when it's reached, is the crucial element in this type of work.



To keep the intake air cooler, the intake air lines have been removed from the sump, where they sat in the hot oil.

The Stroker

Performance Aero is an aircraft engine overhaul shop and manufacturer of many engine parts. Ron Monson has a background in drag racing and has incorporated many of the racing alterations into his aircraft engines. Note: All engines modified from the original manufacturer's Type Certificate Data Sheet are in the experimental category and can't be used on certificated aircraft.

What they've done is taken an original Lycoming IO-540 K1G5 or K1A5 and made it a big-bore stroker. They use these specific engines because they both have large journals for the mains and cranks. More on this later.

First, it's not that difficult to get more displacement by enlarging the bore. Many cylinders have enough stock on them that some can be taken off, allowing the diameter to be enlarged. Many shops are building—actually, having them built—their own cylinders with plenty of sidewall and larger bores.

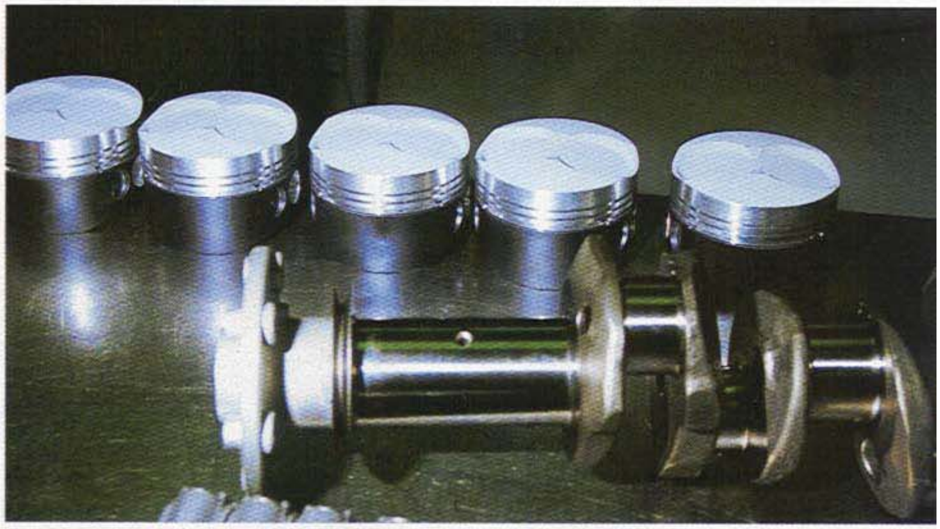
In this case, Monson used cylinders from a Lycoming AEIO-580. This increased the stock 5.125-inch diameter, an area of 20.629 square inches, to a diameter of 5.319 inches and increased the area to 22.2203 square inches. So for an increase in diameter of only 0.194 inches, which is 3.785%, the area increased by 1.5974 square inches, or 7.743%. Of course, with a bigger bore you need a bigger piston. If you're going to build your own piston, you can control the compression ratio and design.

But back to increasing the stroke: The limitation on lengthening the stroke, without building a new case and lowering the crankshaft, is primarily hitting the top of the cylinder and the valves. What Monson did was take the Lycoming crank (we

The new engine will have dual electronic ignition systems or one electronic system and one magneto.

mentioned it had the bigger connecting rod journals) and grind the journals smaller, without touching the part of the circumference farthest out from the crank. The result is that the centerline of the journal is 1/16 of an inch farther out. By decreasing the journal's diameter by 1/1 of an inch, they increased the stroke by 1/8 of an inch. Obviously this decrease is taken into account with the rod bearings.

Originally the stroke was 4.375 inches. So if we add 1/8 of an inch, we're up to 4.500 inches. This, again, is an increase of 2.857%, which doesn't seem worth the effort, but everything adds up. Multiplying the area by the stroke gives us an increase in engine displacement from 541.511 cubic inches, as stock, to 599.948 cubic inches, a 10.791% increase.



Stroking the engine means modifying the crank and the pistons. The other modifications are ways to get more power.

For that extra boost, like when the enemy is on your tail, nitrous can be injected through a specially designed fitting.

But you're thinking you still have to concern yourself with hitting the valves. You're right. So the solution is to move the piston's wrist pin 1/16 inch higher, giving you the necessary clearance but maintaining the 10:1 compression ratio.

The finished product turns out to be 37 pounds lighter, with the accessories, going from 490 to 453 pounds. The horsepower increased from the 300 horsepower of the stock Lycoming IO-540-K1G5 to 450 horsepower at 2700 rpm. Monson also said the TBO should be about 1200 hours.

Other Mods For Power

The new pistons not only increased the compression ratio, they're made from a specially formulated alloy. The tops have been coated with a ceramic to reflect the heat. This has a multitude of effects. If the heat is reflected, the differential between the heat source and the cold sink, the engine itself, is heightened, making the engine more efficient. The cooler the pistons, the cooler the rest of the engine and its oil. To facilitate smooth starts and decrease any chance of the piston scuffing on the cylinder sleeve, the skirts of the pistons have been coated with a P2 molybdenum.

The cylinders themselves were also altered to improve airflow by porting and polishing, and then checking and matching the cylinders on a flow machine. With more cubic inches inside, it's obviously necessary to get more of the fuel/air mixture inside. This was accomplished by using the large intake seats and valves from an IO-720 engine. This increased the intake opening's diameter from 2.210 inches to 2.350 inches. The valves were also cut to five angles for seating. Remember, this is an angle valve cylinder so

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there's less concern about cracking between the valves.

The cam in the new engine has been modified from the original to lift the valves a bit higher and extend the time the valve is open. This will allow for more air to enter the larger intake valve opening. Doing this on the exhaust side will allow more time to scavenge the spent fuel/air mixture.

A new design, which will be available soon, is eliminating the gap in the installed piston rings. Monson did this by having two rings in the same groove. The primary ring was machined so it had a step in it all the way around. The second ring is placed in this step with its gap 180 degrees away from the main ring's gap. He said that in a leak-down test they're getting a perfect 80 over 80. Likewise, the near future will bring titanium connecting rods. These will reduce the weight of each rod by 20% while increasing strength.

Another innovation is the redesign of the engine's sump to remove the intake pipes from the oil they currently sit in. The air plenum will attach to the bottom of the sump, and the intake pipes will go to the cylinders without being heated by the oil. This will decrease the temperature of the intake air, adding a bit of power. Most planes have sufficient room between the bottom of the engine and the cowling for this not to be a problem. For those who desire a shot of nitrous, there's an adapter ready for installation.

To utilize the increased displacment of the engine, it's necessary to get a larger fuel/air mixture in the cylinder. This is accomplished by using large intake valves. This photo shows the difference in valves.

The new engine's spark will be supplied by the Type III Plasma CD electronic ignition by Lightspeed Engineering. Utilization of this will require either dual electrical systems or a backup battery, if used for both spark plugs, or one electronic ignition and one magneto. The starter and alternator will be the lightweight models supplied by B&C specialty products. The fuel system, including the injectors, is by Airflow Performance.