Air Power

Ly-Con is pioneering CNC cylinder-head porting for both certified and Experimental engines.

BY TOM WILSON

Hand porting is noisy, dirty repetitious work, but it is rapidly flexible should a custom port job be required. That's mainly why Ly-Con remains fully vested in hand porting as Oroville Ford demonstrates here. It's also less expensive, helps Ly-Con keep up with its high-volume workload and allows the company to meet its contract development work with the Continental and Lycoming factories.

Porting cylinder heads sounds like pure hot rodding, and it can be, but the reality is that a large number of certified and non-certified engines have cylinder heads ported by hand. As Ken Tunnell, the main man at engine specialist Ly-Con notes, nine out of 10 engines passing through his shop receive ported cylinder heads. It's a valuable part of the engine blueprinting that goes into the detailed builds and overhauls that boutique builders such as Ly-Con provide.

What is porting? It's the massaging of the air passages (ports) leading to the intake and exhaust valves that are cast into the cylinder heads at the factory. These passages are admittedly short sections of the engine's total air path, which runs from air filter to exhaust outlet, but the ports and especially the environment immediately surrounding the valve seats and valves are critical in defining how efficiently the engine breathes. Better understood now in the age of computer modeling and sophisticated observational techniques, minor changes in shape, volume and

Corky Estes is the airflow development lead at Ly-Con. Seen here checking a parallel valve Lycoming jug, he can just as often be caught developing new port shapes for a variety of advanced custom powerplants. Much of the crowd-pleasing power of Reno racers or 400-hp aerobats such as Sean Tucker's and Jim LeRoy's were developed on this bench.

surface texture of the ports can fundamentally improve engine efficiency.

Hand Porting

Traditionally porting is done by hand using a high-speed rotary motor—your basic die grinder—fitted with a variety of carbide-tipped cutters and sanding rolls. The technician skillfully reshapes, resizes and retextures the ports while the cylinders are disassembled. It's tedious, dirty work.

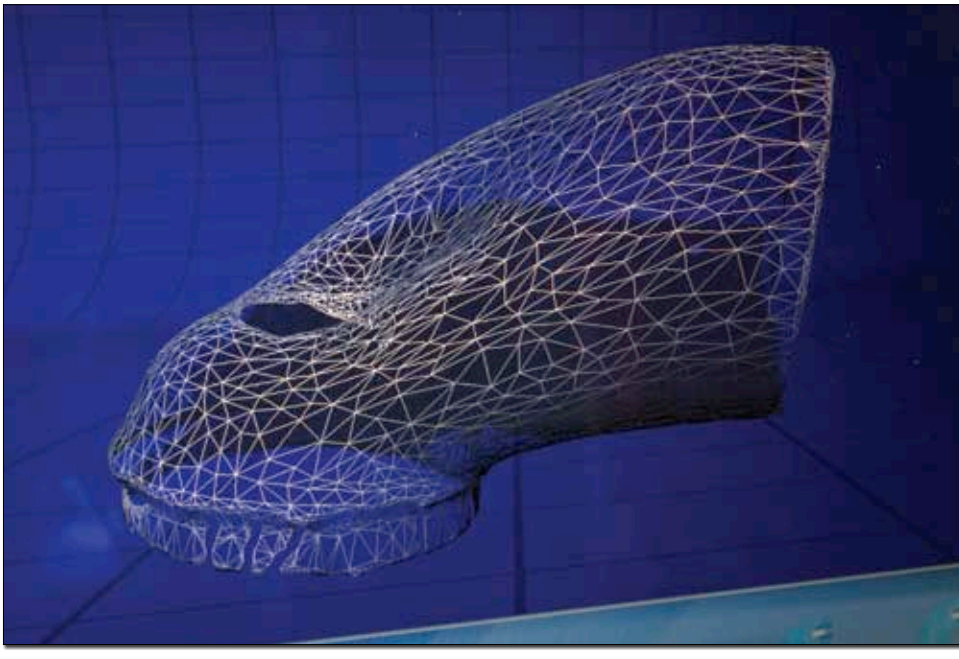
The trick, of course, is arriving at the optimal shape, size and texture. This is a trial and error process, something Ly-Con went through decades ago when it started hand-porting aircraft cylinders. Cylinders are ported using a calibrated vacuum cleaner/air pump called a flow bench to check progress. Follow-up dyno testing is also required, as what looks good on the flow bench does not necessarily translate into progress in the finished engine. Once a shop has arrived at a proven port design, it can recreate it endlessly for the same basic engine and cylinder head combination as a validated performance enhancer. Clearly this requires an experienced, skilled head porter on staff.

Carefully contoured and smoothed, this pair of CNC-ported Lycoming 360/540 ports is located to within 0.0001-inch of their respective valve guides thanks to CNC accuracy. The small flat spot facing the camera on the intake valve guide is there as an airflow aid.

Let's also note the porting detailed in this article is relatively mild. On certified engines porting involves buzzing off of casting flash, smoothing all surfaces of casting roughness (the pebbly grain left by casting) and the minor reshaping of transitional areas where the air must make sharp turns. In other words, the port cast by Continental or Lycoming is cleaned and adjusted, but not redesigned.

On more hot rod Experimental engines a general reshaping of the port may be accomplished. On the most radical custom jobs—rare and expensive custom work reserved for pylon racers and air show performers—the port may be completely reshaped and relocated by

Ly-Con's desktop scanner takes both white-light and laser light scans of the port plug. Here the laser array feels its way along the port plug, while the plug rotates atop the scanner's turntable. The laptop computer captures the data; total scan time is approximately 3 minutes.



Once digitized, the port model can be viewed, rotated and modified in many ways. This wire frame can just as easily be exchanged for a solid view, for instance. The most important task, however, is to convert the scanned file into a series of commands the CNC machine understands.

Photos: Tom Wilson

welding up some of the port and redesigning it with the die grinder.

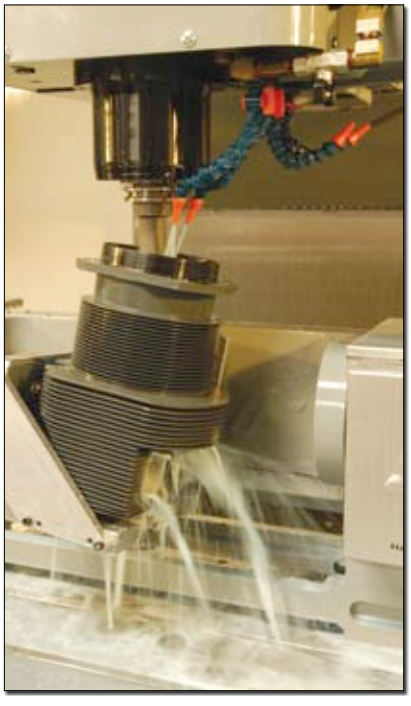
CNC Porting

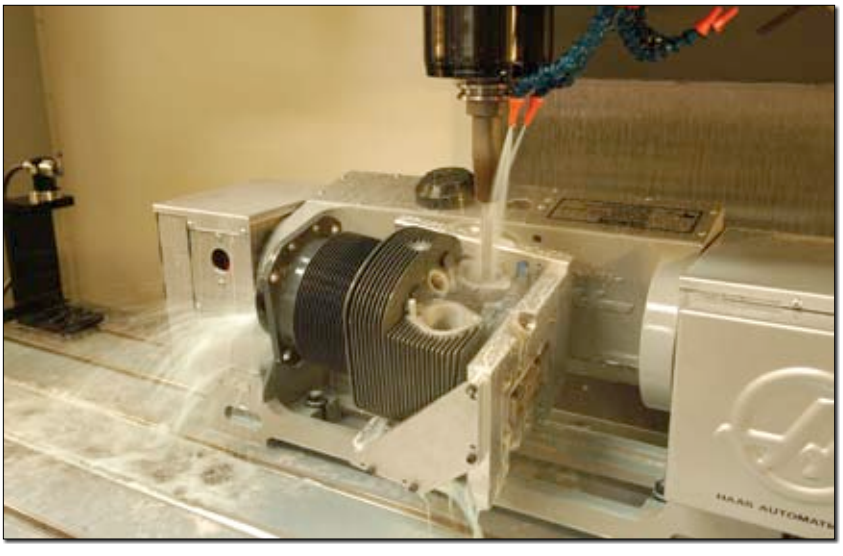
A recent porting improvement is turning the grinding over to a CNC robot. Such computer numerically controlled machining offers several porting advantages, but the main ideas are the CNC machine is extremely accurate, able to replicate the same port every time, precisely place the port relative to the valve no matter how variable the cylinder casting and via its accuracy and repeatability can generate textures a human cannot.

Thanks to its accuracy and surface texture, a CNC ported cylinder head slightly outperforms the same level of hand porting, according to Ly-Con. The improvement is mainly in the intake port, where the CNC machine leaves a series of visible steps that act like golf-ball dimples, breaking and bending the

Ly-Con's 20-hp Haas CNC center is where the cutter meets the aluminum. The company is just beginning to explore the 2007 machine's capabilities; its speed and precision are rare commodities in general aviation engine work.

Loading the work, in this case cylinders, into the CNC machine is done one at a time as Bryan Tunnell demonstrates. Even so, the CNC porting workflow outpaces hand porting on a daily basis. Once the ports are machined, the cylinder is moved to the Serdi machine for the final step: valve and seat machining.





Replicating arm and wrist movement takes five-axis motion. The Haas machine does this with the usual three-axis table, plus a two-axis cradle bolted to the table. It's fascinating to watch the machine move the work in all five axes simultaneously. Essentially the cutter moves down the port in a carefully controlled spiral; access to both flange and cylinder apertures on the jug is easily accomplished.

boundary layer more sharply than the smoother texture of hand porting.

On the exhaust side, Ly-Con polishes the CNC-generated steps out because they give exhaust residue a perfect toehold. Thus, the reduction in carbon buildup trumps the airflow improvement from the steps.

About the only disadvantage to CNC porting is extra cost. It takes a machine capable of cutting in at least four axes, and it's better to have a five-axis CNC machining center to replicate human arm and wrist motion. Such machines represent an investment far in excess of six figures, so the payback has to come from somewhere.

In fact, the high cost of CNC head porting has severely limited its migration from the relatively high-volume hot rod automotive universe to the aviation world. To date Ly-Con's CNC head porting is a general aviation exclusive.

Besides the cash investment, there is the additional time it takes a shop such as Ly-Con to develop the programming to run the CNC machine. Hand porting "software" develops naturally as the technician practices his craft with no intermediate steps, but building CNC software is best developed using some physical structure that can be digitized.

Ly-Con has handled software development by arriving at the desired port shape via hand porting, then making rubber molds of the idealized ports. These male models are then scanned by a laser to generate a digital file, which is worked into CNC software. It's proven

Writing CNC software is eased immensely if a male model of the port is available. Ly-Con formed the necessary molds with latex rubber, a common head-porting technique.

an accurate method, but it's fraught with seemingly endless new steps and techniques to master. Like the checks written for the CNC center, the arduous development process needs to be accounted for by the green-eyeshade department.

Ly-Con's CNC Cylinders

At press time Ly-Con was concentrating solely on its bread-and-butter Lycoming 360/540 parallel-valve cylinders for the CNC porting program. Once the parallel Lycomings are up to speed, Ly-Con says it'll move to 470, 520 and 550 angle-valve Continentals, then angle-valve Lycomings and finally 200 and 300 parallel-valve Continentals. No timetable is in place for the upcoming engines, but the learning curve has been steep for Ly-Con on the CNC machine, so patience is a virtue. That said, once the Ly-Con has a couple of engines noodled out, the remaining applications should

From the combustion chamber side the CNC ported head shows some registration lines in the smaller exhaust port, plus the opened area behind the bronze-colored valve guide in the intake port. No CNC work is done to the combustion chamber, nor have these valve seats been cut yet on the Serdi machine.

come more quickly as Ly-Con has the port shapes developed and needs only to digitize them.

Getting back to the 360/540 parallel cylinders, Ly-Con's general philosophy is to make them no larger in cross sectional area—they're already slightly too voluminous as cast. The stock cylinder is put in the CNC machine using the valve guides for location and the rocker cover bolt holes as tie-down points. The CNC machine then lightly whittles the entire port, reworks the valve seat-to-port transitions and rationalizes the shape and cross section around the valve guide boss.

From the CNC machine the cylinder is transferred to Ly-Con's Serdi head and seat machine. This is another quality machining center that's dedicated to cutting the valves and valve seats. Compared to the traditional stone-based valve-grinding systems, the Serdi is very accurate. It holds tolerances to 0.0001-inch; stones are good to just 0.0015-inch.

While the Serdi and CNC machines are independent of each other, it's clear the Serdi's accuracy complements the CNC's ability to place the port in precise relationship with the valve seat, maximizing the airflow gains.

Ly-Con is turning 360/540 parallel-valve cylinders out as fast as it can. Pricing is $350 per cylinder for CNC porting. Hand porting is not going away at Ly-Con, either, and that option for the same cylinders is $250 per jug.

What's It Worth?

Assigning hard and fast performance improvements to port work is difficult at best. So much depends on the combination of parts throughout the engine, plus the dyno doing the measuring; weather even matters. In fact, quoting hard numbers for power improvements is such a minefield that Ly-Con would just as soon pass on the subject.

Still, Ly-Con has some rules of thumb about how much horsepower the porting is worth. Using flow bench and dyno data from experience, shop foreman Bryan Tunnell says, "Parallel valve cylinders are improved more than angle valve

An inspection of as-cast Lycoming 360/540 parallel valve ports shows the generally rough surface texture, along with casting lines and smaller scabby areas. The intake port (the one without studs) seems to present the roughest lines, and in the most critical areas.

heads because the parallel cylinders are worse to begin with, so they have more room for improvement.

"With hand-porting, the parallel valve jugs make about 5 horsepower more per cylinder than stock. With hand-porting, the angle valve jugs gain about three horsepower per cylinder.

"With CNC porting, we don't know yet for sure how the parallel valve cylinders do, as we don't have conclusive dyno data on them. But they might pick up an extra horsepower per cylinder."

Assuming a 6 hp/cylinder gain for CNC ported parallel valve 360/540 cylinders, that yields a 24-hp total gain on a 360 and a 36-hp gain on a 540 from the porting alone. Again, these numbers are strictly for guidance; your mileage will vary, as the saying goes.

Furthermore, Ken Tunnell added that from the very first dyno session with CNC-ported cylinders, he's noted the EGTs are more even cylinder-to-cylinder. This jibes with the CNC and Serdi accuracy that centers every port around every valve guide, regardless of core shift in the parent cylinder casting. With each port/valve/seat relationship identical, each cylinder is bound to flow more consistently compared to its neighbors. This should play favorably when leaning the engine in conjunction with an engine analyzer and balanced fuel injectors.

For customers with Experimentals, adding compression with Ly-Con's NFS line of forged domed pistons helps

Ly-Con CNC ports Lycoming, Continental and Superior cylinders for certified and Experimental aircraft. Here a CNC-ported Lycoming 360/540 jug is matched with black cylinder paint, gold alodine anti-corrosion treatment on the head and a fully coated 10:1 NFS piston. With the higher compression, the combination is for Experimental aircraft only, but offers a real boost in performance and efficiency, plus some cooling and rust protection tweaks.

Here are the same model ports after CNC-ing. The intake easily shows the numerous lines or "steps" formed by the precisely advancing cutter; the exhaust shows a few lines in the port's "bowl" just above the valve seat, but has otherwise been polished smooth to hinder carbon buildup.

a bit more. Given CNC porting and 10:1 compression, 300- to 310-hp 540s are the current norm before getting into exotic aftermarket induction and exhaust systems. Four-cylinder IO-360 customers can expect about a 30 hp gain with porting and higher compression pistons, the company says.

Best of all, these power improvements are really efficiency improvements. They come from a fundamental betterment of engine breathing, not from turning the engine faster or tuning parameters such as advanced ignition timing or camshaft profile. If increased fuel economy and not horsepower is the major goal, the engine can be run at the original power levels using less fuel (the engine is breathing more easily and uses less fuel to pump air through itself). Translation: faster climbs and more economical cruises. Not bad for a little attention to airflow detail. ∓

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