The Truth About Rotaries

Fallacies have long obscured facts in the history of rotary engines

History.net
Drew Ames

As in subsequent conflicts, airplane technology progressed at a rapid pace during World War I. In 1914 production aircraft speeds topped out around 80 mph, and most pilots still relied on wing-warping to change direction. By war's end, top speeds approached 150 mph, and many planes exhibited technologies considered standard today. Yet the war years also saw the advent of designs and technologies that, like wing-warping, were evolutionary dead ends. Chief among these was the rotary engine.

Unlike stationary aircraft engines, in which a turning crankshaft drives the propeller, in rotaries the whole engine spins around a stationary crankshaft. The prop is bolted directly to the engine and spins with it. The primary reason for the rotary configuration was to provide adequate cooling. Because the cylinder heads are perpendicular to the slipstream and whirling through the air, the engine stayed within safe temperature limits. Engine cooling was a challenge in the first decade of the 20th century, even with water-cooled engines, and rotaries presented a viable solution to the problem.

The fact remains, however, that rotary engines faded from use almost immediately after the war. Popular histories give oft-repeated but incorrect reasons for their quick decline: They were two-stroke engines that mixed the oil and fuel, had no throttles and were tricky to fly because of the gyroscopic force from the spinning engine. At best, there is only a kernel of truth to these misconceptions, and none explains why rotaries ended up as a dead-end technology despite being so widely used.

Rotary engines were for a time the best and most ubiquitous aircraft power plants available. By some estimates, they powered as many as 80 percent of WWI aircraft. Half of the top 10 aces' planes had rotaries. The majority of Sopwith and Nieuport designs used them. German aircraft manufacturers tended to prefer inline water-cooled engines, but several prominent designs by Fokker and others mounted rotary engines. Perhaps the most famous rotary-powered plane was Manfred von Richthofen's all-red Fokker Dr.I triplane, which he was flying the day he died. Of course rotaries also powered many less well known aircraft, such as the Caudron G.3 single- and G.4 twin-engine reconnaissance planes.

A primary reason for their popularity was that rotary engines had very good power-to-weight ratios (often given as weight-to-power ratios) compared to water-cooled engines. The Liberty V-12 engine weighed 845 pounds without oil and coolant and produced 449 hp, for a weight-to-power ratio of 1.9 pounds per horsepower. With oil and coolant, however, the weight-to-power ratio climbed to 2.6 pounds per hp. Another common water-cooled engine, the HispanoSuiza 8b used in Spad XIII fighters, weighed 520 pounds dry and had a weight-to-power ratio of 2.6. In contrast, the 330-pound, 160-hp Gnome Monosoupape 9 Type N rotary had a ratio of just over 2 pounds per hp.

The lighter engine weight meant that rotary-powered airplanes tended to be lighter overall and more maneuverable than planes with water-cooled inline or “vee” engines. Eddie Rickenbacker, America’s top WWI ace, had an encounter early in his career that illustrated his rotary powered Nieuport 28’s maneuverability versus a heavier fighter. He related the story in Fighting the Flying Circus: “Both of us continued dead ahead at each other for twenty seconds or so until we arrived almost within shouting distance, when I discovered to my great relief that he wore the blue center cocard of a Frenchman and his machine was a Spad. We had fortunately neither of us fired a shot. Suddenly I saw the French pilot zoom up over me and attempt to get on my tail. Whether joking or not, I couldn’t permit such a maneuver, so I quickly darted under him and got the best position myself. The Nieuport can outmaneuver a Spad and has a little faster climb; so the stranger soon found he had his match.”

The first mass-produced rotary engine—the 7-cylinder, 50-hp Gnome Omega—debuted at the Paris Air Show in 1908. It was the product of three French brothers, Louis, Laurent and Augustin Seguin, whose goal was to produce a lightweight, reliable and relatively powerful engine specifically for aircraft. Prior to the Omega, airplane power plants were adaptations of either heavy, water-cooled automobile engines or motorcycle engines, which often experienced cooling problems. The eldest Seguin brother, Louis, formed the Société des Moteurs Gnome in 1906, and immediately began developing prototypes. Their first prototype was a 5- cylinder radial, but the second was a 7-cylinder rotary that differed little from the final production version.

The Seguin brothers did not invent the rotary engine. Hungarian immigrant Stephen Balzer had developed a rotary in 1894 for use in automobiles. The Seguins’ major innovation was to create a lightweight rotary using careful machining. Each cylinder, with all the cooling fins, was machined from a solid billet, resulting in strong but thin cylinder walls. Their second major accomplishment was successfully promoting their new power plants. Between 1908 and the start of WWI, Gnome produced approximately 4,000 of them and set up subsidiaries in most industrialized countries.

Three firms produced the majority of rotary engines that saw use during WWI: Gnome, Le Rhône and Clerget. The British Bentley engines were license-built modifications of Clergets. The German-built Oberursel engines, used in Fokker aircraft such as the Dr.I, were primarily license-built copies of Le Rhônes, although Oberursel produced variations during the war years. Between 1908 and the end of the war, different firms created a variety of rotary configurations: 5-, 7- and 11-cylinder engines; double-row 18-cylinder engines; and a rotary made by Siemens und Halske with a propeller gear to turn the prop in the opposite direction of the engine. The most common configuration, however, was the 9-cylinder rotary. These were produced in the tens of thousands compared to, for example, only 1,200 of the more exotic Siemens motor.

Regardless of configuration, all rotaries are four stroke engines. A common fallacy about rotaries is that they are two-stroke, like today's chainsaw engines. That misconception probably arises because of confusion over how they are lubricated. Regardless of make, rotaries share a total-loss oil system. The air, fuel and oil are delivered to the engine through a hollow crankshaft, creating the impression that the oil mixes with the gas as in a two-stroke. In fact, the oil and fuel do not mix. Castor oil, often the famous Castrol brand, was the preferred lubricant precisely because the oil maintained its lubricating qualities even under pressure and high heat. It did not ignite with the fuel as it passed through crankcase, cylinders and out the exhaust.

Rotaries have odd numbers of cylinders so that the ignition can be timed to fire every other cylinder, with a firing order of cylinder 1, then 3-5-7-9-2-4-6-8. The alternating firing order results in smooth running. Most radial engines have an odd number of cylinders for the same reason.

The most persistent misunderstanding about rotary engines happens to have a grain of truth. Many books on WWI aviation state that rotaries had no throttles and always ran at full speed; the only way to slow them was to temporarily turn them off via a coupez or "blip" switch that cut the ignition. Fred Murrin, a present-day pilot of replica WWI warbirds who's been flying rotary aircraft since 1993, cleared up the confusion: "All rotary engines had a way to control [engine speed] except the 100-hp Gnome. All had carburetors except the 100- and 160-hp Gnomes."

So in truth only one rotary, the 100-hp Gnome, fits the typical description. Naturally it proved very unpopular with pilots, since they couldn't adjust speed by increasing or reducing power. Canadian born ace and 1st Pursuit Group commander Harold Hartney, who flew various planes powered by the 100-hp Gnome, stated in his memoir Up and At 'Em that it was a horrible engine.

Manufacturers developed ways to regulate engine speed by manipulating the relationship among the carburetor, mixture control (or fine adjustment as it was called at the time) and sometimes the ignition. Different types of engines used different systems.

Le Rhône and Clerget engines (and by extension Oberursel and Bentley power plants) had two valves per cylinder: one for inducing the gasoline/air mixture, and one for venting the exhaust after the mixture ignited. Both had inlet pipes going from the crankcase to the cylinder heads. The air and fuel mixture was drawn up the pipes by a combination of the vacuum in the cylinder heads and the rotating force of the engine. The Le Rhône had a rocker arm that worked both valves on each cylinder and was in turn actuated by a single tappet rod connected to cams in the crankcase. The Clerget had two separate valves and two tappet rods per cylinder. Both featured simple carburetors, adjusted by throttles, that varied the amount of air going into the fuel/air mixture. More air coming through the carburetor resulted in a larger volume of fuel/air mixture being ignited in the cylinder, and a faster power stroke of the piston, producing more engine speed.

Different air densities at altitude and the simple nature of the carburetors necessitated a way to adjust the fuel as well. Murrin explained: “Rotary engines that had carburetors, which were simple slides with long metering needles, required a fine mixture control valve upstream in the fuel line. So the pilot had to mix the fuel and air himself, which wasn’t that difficult. It is done much the same as leaning a modern airplane engine. The rpm range of a rotary engine was from about 500-600 rpm at idle to 1,200-1,300 rpm at full speed.”

Gnome engines did not have carburetors or throttles. The only direct control pilots had over the fuel and air mixture was the fuel flow fine adjustment lever in the cockpit. Gnomes were often called Monosoupape engines, French for “single valve.” The single valve both induced air for the fuel/air mixture and vented the exhaust after the mixture ignited. In place of a valve for inletting fuel, the 100- and 160-hp Gnomes had inlet ports toward the bottom of the cylinders. Because the Gnome power plants did not have a throttle or carburetor, pilots could vary the speed of the engine only by interrupting the ignition. The 160-hp Gnome improved on the 100-hp version’s simple on/off switch by providing a variable ignition timing selector.

Andrew King, a pilot and WWI aviation enthusiast who grew up near Old Rhinebeck Aerodrome, recalls the sounds and smells of Gnome engines as some of his earliest memories. Having flown three Gnome-powered planes, he’s now building a Nieuport 28 replica to house his own Gnome. King explained how the selector switch works: “The 160 was ‘throttled’ using an ignition interrupter. There are five positions on the switch: 4-3-2-1-0; 4 is full power and normal firing order 1-3-5-7-9-2-4-6-8, and 0 is off. On position 3 every other ignition pulse is skipped, so the firing order is 1-5-9-4-8-3-7-2-6, and it takes four revolutions instead or two for all cylinders to fire—this is half speed. On position 2 it takes eight revolutions to fire all cylinders, 1 (skip 3-5-7), 9 (skip 2-4-6), 8 and so on. On position 1 it’s one eighth speed, and takes 16 revolutions to complete the firing order—it sounds like it’s running on one cylinder.”

According to Murrin and King, often-repeated tales about tricky aircraft handling due to the gyroscopic effects of rotating engines—that the spinning mass of the engine made for very quick turns to the right and slow turns to the left—are exaggerated. “When you hear the stories about rotary engines being hard to fly, the problem was with the inexperienced people flying them,” explained King. “When I made my first flight in a rotary-powered aircraft, I landed and then realized that I hadn’t noticed any gyroscopic effects. An experienced pilot automatically compensates for those things. Turns to the right might be a little quicker, but that is because the rotary engine tends to pull the nose down [in that direction], and you make a quicker descending turn than you make a climbing turn.”

Murrin agreed: “There are small gyroscopic effects but nothing close to the exaggerated tales often repeated in print and in documentaries. You adjust for them much the same way you would if you were flying in mildly gusty conditions. The torque reactions are most notable during takeoff and gliding in for landing when ‘blipping’ the engine.”

Other factors had a more pronounced effect on aircraft handling. King noted that all the early rotary-powered planes had a lot of adverse yaw (the tendency of the plane's nose to point in the opposite direction of a bank when star ting a turn), and all were tail-heavy, leading to a certain amount of instability in their handling.

Rotary engines were generally reliable, compact, powerful for their weight and did not adversely affect aircraft handling. And Hartney wrote in Up and At 'Em that it took only four hours to overhaul the Gnomes in Nieuport 28s as opposed to four days for the HispanoSuizas in Spad XIIIs. So why did rotaries quickly fall from favor after the war ended?

King pointed to improved technology: "The main reason for rotary engines was cooling, and when engine makers figured out how to cast cylinders with adequate cooling fins, they were able to eliminate all the complexity of ignition and fuel/air mixture that they had with rotary engines." Murrin agreed, adding a logistical consideration: "Rotary engines became quickly outdated for a couple of reasons, but mostly because of the large quantity of Castrol required to keep a squadron of rotary-powered airplanes in the air. Most rotary engines consume about five or six quarts of oil per hour."

In addition, perhaps the biggest reason why rotary engines were abandoned was that the very nature of their design limited the overall power they could develop. Drag from the spinning engine, which reduced available power by about 10 percent, was part of the problem. But the main reason was that the long fuel/air intake route—through the hollow crankshaft, into the crankcase and via intake pipes or ports into the cylinder—limited the amount of mixture that could be drawn into the cylinders, which in turn created a power ceiling. The largest and most powerful widely produced rotary, the Bentley BR2, weighed 498 pounds and produced 230 hp. While at the time that compared favorably with inline engines, it was also the practical limit for rotary development. Inline engine developers continued to push their designs to 300 hp and beyond, and with the advent of better metallurgy and manufacturing technologies, engine designers started to develop practical radial engines. Radials have many of the same advantages of rotaries—good power-to-weight ratios and simple cooling— without their inherent inefficiencies.

Don't count rotaries as completely dead just yet, though. Groups of enthusiasts worldwide are restoring original WWI aircraft or building new replicas to exact original specs. Consequently, there is strong demand for working, original rotary engines. Enough demand, in fact, for a firm to begin making new rotaries. Fred Murrin now works at The Vintage Aviator Ltd. in Wellington, New Zealand, helping to manufacture Le Rhône and Oberursel replicas. "It's very interesting building these engines brand new, from scratch," says Murrin. Hopefully it won't be long before more pilots can experience rotary-powered flight, and more people can see these wonderful engines in action.