Resurrecting rigid rotors

Helicopters are doing things none have ever done, using a principle that was rejected decades ago.

by Jonathan Eberhart

The helicopter has always been an ornery beast. Since nothing has come along that could beat it at hovering or taking off from a dime, it has become all but indispensable in a variety of unusual jobs. But the fact remains that for years the chopper has just been trudging along in the dust, compared with what it could be doing, while its fixed-wing brother has been getting more and more sophisticated.

At long last, however, the helicopter is about to emerge from its Dark Ages. The key is so simple that it's hard to believe it works. No elaborate electromechanical wonder, it was developed by engineers who went back more than 40 years for inspiration.

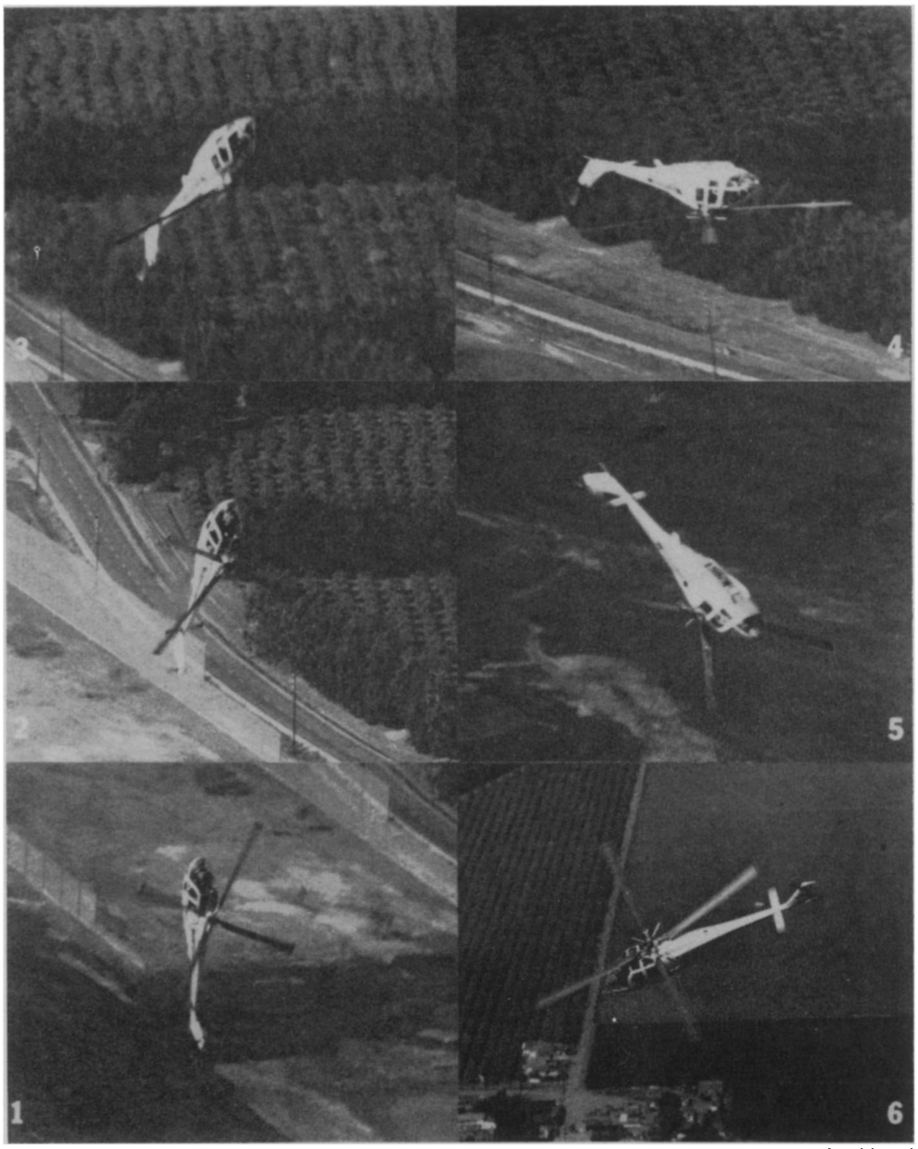
At first, Juan de la Cierva had no interest in helicopters; he was strictly a fixed-wing man. In 1912, at age 17, he helped build the first flyable airplane in Spain. A few years later, however, when a three-engined biplane of his design stalled during a turn and crashed, he decided to throw his genius behind a slower, safer aircraft.

Since the lifting power of a wing depends largely on the speed at which air flows over it, de la Cierva reasoned that in a slow-flying aircraft, the wing or wings would have to be moving through the air faster than the fuselage. The best way to do this, he decided, was to have the wings rotate around a vertical axis. The vehicle he developed, later named the autogiro, had a conventional front engine and propeller, as does a fixed-wing craft. It got its lift, however, from a helicopter-style rotor, driven like a pinwheel not by a motor but by the airflow.

When the autogiro came along, helicopters with powered rotors were already in existence; the first had flown in 1907, more than a decade earlier and only four years after the Wright brothers' triumphant fixed-wing flight. The autogiro had an edge on the helicopter, however: because the helicopter's rotor was driven by an engine, which produced torque, or turning power, the fuselage tended to react by turning in the opposite direction. This required some kind of compensation—a small rotor on the tail, or the use of two main rotors going in opposite directions—not necessary with the autogiro's free-turning rotor.

Unfortunately, helicopter and autogiro also shared a common problem. De la Cierva found an answer, and his solution has influenced the design of holicopters ever since; it has also, literally, been the weak link between the chopper and its true potential.

The trouble was that in horizontal flight, the advancing rotor blade has a higher relative air speed than the retreating blade, and thus produces more lift. This unequal lift produces a force that tends to stand the helicopter on its head.



Lockheed

Loops, rolls and other formerly fixed-wing tricks are a snap for the RR.

At first, de la Cierva tried contra-rotating rotors, hoping that the two unequal lifting forces would cancel each other out. He found, however, that since one rotor was operating in the disturbed air stream of the other, the system was inefficient and the two rotors did not produce equal lift, so the cancellation was not complete.

After building one prototype, the designer went back to the single rotor and tried several other ideas, including a horizontal tail with elevators that could be operated individually. When two more prototypes had suffered a

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variety of ignominious crumplings without ever getting past the takeoff run, de la Cierva came up with his hinge.

On his fourth prototype autogiro, which first flew in January of 1923, each of the four rotor blades was hinged at the rotor hub. Centrifugal force kept the blades roughly horizontal during flight, but the hinges allowed each individual blade to rise and fall to compensate for variations in lift. This equalized the lift distribution, with no effort from the pilot, and served as well to reduce the bending stresses at the blade root. But it meant that the rotor's gyroscopic influence—its tendency to hold its orientation and thus stabilize the vehicle—had largely disappeared, since the fuselage was no longer rigidly connected to the rotor but hung almost like a pendulum instead.

One hinge led to another. When the introduction of the flap hinge enabled the blades to move up and down, another already troublesome effect became worse. This was the tendency of each blade to slow down and speed up as its flapping motion carried its center of mass through an arc that brought it farther and nearer to the rotor shaft. So de la Cierva introduced another pivot, the lead-lag hinge.

For decades helicopters have used de la Cierva's hinges in what is called the articulated rotor. The chopper now fills numerous vital roles, from transporting heavy equipment to emergency service in Vietnam. Compared to a fixed-wing plane, however, the articulated rotor still leaves a lot to be desired, usually requiring two hands, two feet and at least one head to fly it.

In 1957, a group of engineers at Lockheed-California Co. took a look at all types of vertical takeoff and landing (VTOL) aircraft in a search for a safe, inexpensive design that could be sold to a mass market. They concluded, in essence, that the helicopter was the obvious choice, but that those hinges had to go. In a sense, these engineers were flouting history, looking back at the rigid rotors.

They tried a succession of ideas using small radio-controlled models with two-, three- and more-bladed rotors, along with other variations, until Irven H. Culver, a now-retired engineer with no college degrees but with more than enough aeronautical horse sense, came up with the brainstorm.

The first helicopter to embody Culver's system took off in November of 1959. Called the CL-475, it had a three-bladed rotor, rigidly mounted to its shaft, and beneath which was a small ring-shaped device almost like a halo over the cockpit. The ring, since refined to a cross-shape like a miniature rotor, was the control gyro—the heart of Lockheed's rigid rotor design. From the primitive CL-475, the system has been developed until it is now the basis of what will soon be one of the most remarkable weapons in the U.S. Army's arsenal, the AH-56A Cheyenne. Armed to the teeth, and equipped with a laser beam rangefinder, an automatic infrared weapon-aiming system and other sophisticated devices, the Cheyenne will be the first helicopter ever designed from the start as a fighting chopper.

Back in the early 1920's de la Cierva had had one problem, besides the unequal lift, that he simply couldn't solve and still keep the rigid rotor. If one tries to tilt a rigid rotor by tilting the rotor shaft, the plane of the rotor blades will move around until it is tilted at a right angle to the desired direction. This is called gyroscopic precession.

Lockheed

Lockheed's first rigid rotor: a halo.

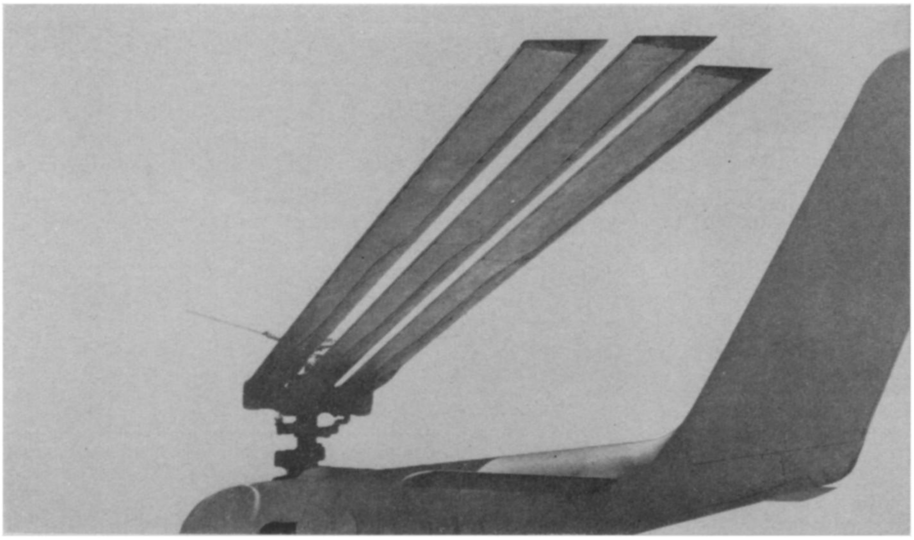
When de la Cierva tried to control a rigid-rotor autogiro by giving the craft a fixed horizontal tail with elevators to tilt the fuselage—and thereby the rotor shaft—the autogiro, instead of going forward, fell over on its side.

"Our contribution," says Lockheed-California vice president Jack G. Real, "was the solution of de la Cierva's problem."

In the Lockheed system, the pilot operates a control stick which is connected not with the main rotor at all, but with the control gyro. When the pilot moves the stick forward, a force is applied to the side of the gyro, causing the gyro to precess around 90 degrees, so that it is tilted forward. This produces a difference between the plane of the gyro and the plane of the rotor. The gyro is connected to the rotor in such a way that this difference causes the pitch of the rotor blades to change, producing increased lift on one side of the rotor. Since the rigid rotor is in effect a gyro itself, it precesses around until it is tilted in the same way as the control gyro—forward. And so moves the chopper.

Besides making de la Cierva's old problem of gyroscopic precession become its own cure, the modern rigid rotor also automatically compensates for the turnover tendency of unequal lift distribution. During horizontal flight, changes in lift over the rotor, which cause tiny changes in the attitude of the aircraft, are counteracted by the changing pitch of the rotor blades, induced by the stabilizing control gyro. This also compensates for wind gusts.

Between Lockheed's first rigid rotor, the CL-475, and the Army's Cheyenne, several other versions were built. The first of these was the XH-51A, built jointly for the Army and Navy, and later for the space agency. The ring-shaped control gyro was refined into a mechanically simpler cross and relocated above the rotor. Since high speed was of particular importance to the military, everything was done to reduce aerodynamic drag. All external rivets were set flush with the aircraft skin, a retractable landing gear was installed and the vertical tail was angled so that the tail rotor would not be a source of air resistance at high speeds. Even the main rotor shaft was tilted forward six degrees so that the fuselage would hang from it at the least-drag-producing angle. Turbine-powered, the 51A reached more than 200 miles per hour.



Lockheed

Wind tunnel tests of a stowable rotor presage an even faster chopper.

For still more speed, engineers added a stubby fixed wing, and then mounted on it, just outside the left window of the cockpit, a jet engine capable of 2,500 pounds of thrust. Called a compound helicopter because of its wing-and-rotor combination, this modified 51A last year flew faster than any other rotorcraft in history—302.6 mph. Lockheed test pilots have taken rigid rotors through loops, rolls and other figures difficult or impossible for a conventional chopper.

The Cheyenne is a compound helicopter with a fixed wing, but it has no auxiliary jet engine. Nevertheless it will have a top speed of more than 250 mph, almost twice that of the armed choppers now in Vietnam. The company is also studying the rigid rotor concept for use in a commercial passenger-carrying helicopter.

Still in the brainstorm-and-windtunnel stage is the "stowed rotor," which would allow a compound helicopter to reach cruising speed, then stop the rotor blades, fold them back and lower them into a storage well atop the fuselage. The foldable rotor, the company claims, would enable high-density runs at jet speeds of more than 500 mph.