Autogyro

Modern Autogyro, ELA-07, Casarrubios del Monte Airfield, Spain, 2004

An **autogyro** (only an **autogiro**™ when produced by the Cierva Autogiro Company or one of its licensees (see below), sometimes called a **gyroplane**, **gyrocopter**™, or **rotaplane**) is an aircraft supported in flight by an unpowered rotor. Though the autogyro resembles a helicopter, it is driven in flight by an engine-powered propeller similar to that of an airplane. Often mistakenly characterized as a hybrid between an airplane and helicopter, the autogyro is a distinct type of aircraft that made its first successful flight on 17 January 1923 at Cuatro Vientos Airfield in Madrid, Spain, predating the first successful helicopter by 13 years. All helicopters utilize rotor technology first developed for the autogiro: the helicopter owes its existence to the brilliant work conducted by Juan de la Cierva and his associates.

General characteristics

Autogyros can take off and land in significantly smaller areas compared to airplanes, and depending on the model, can operate from helipads. When fitted with a jump start feature, an autogyro can takeoff from a standing start into forward flight, accelerate in ground effect, then commence a climb; hovering capability is not available however since the rotor is always declutched before the autogyro leaves the ground. If rotor collective pitch control is provided, an autogyro can execute a collective flare; otherwise landings are always made with a cyclic flare.

Certificated autogyros flown by trained and qualified pilots are notably safe. As intended by la Cierva, the rotor always turns regardless of the airspeed of the aircraft, though as airspeed decreases rotor rpm reduces to a minimum value at zero airspeed. Reduction of engine power increases the descent rate, though the autogyro remains fully stable and controllable. Directional control, provided by a rudder, can become nonexistent at low airspeed and low propeller thrust. For example, the Air and Space 18A gyroplane rudder rapidly loses effectiveness below 50mph airspeed when the engine is throttled.

Most autogyros are neither efficient nor very fast (for one exception see Wing Commander Ken Wallis, below - around 120mph on 60bhp). Fixed-wing aircraft are faster and use less fuel over the same distance, helicopters generally require more power (and hence fuel) than a fixed wing aircraft (or autogyro) for the same top speed/load etc. It must be noted, however, that large scale autogyro development ceased prior to WW2 and with few exceptions has not benefitted from rotary wing developments applied to helicopters.

Gyroplanes are typically more maneuverable than fixed-wing aircraft, but do not hover as does a helicopter. When helicopters became practical, autogyros were neglected for nearly 30 years. They were however at one time used extensively by major newspapers and by the US Postal Service for mail service between the Camden, NJ airport and the top of the post office building in downtown Philadelphia, PA.

As the infrastructure for service, repair, training and building increases the number of autogyro users may increase.

Autogyros can be of tractor configuration with the engine(s) and propeller(s) at the front of the fuselage, or pusher configuration with the engine(s) and propeller(s) at the rear of the fuselage.

Early autogyros were fitted with fixed rotor hubs, small fixed-wings and airplane-type control surfaces. At the low airspeed at which autogyros can easily operate, the airplane-type control surfaces became ineffective and could readily lead to loss of control, particularly during landing. The direct control rotor hub, which could be tilted in any direction by the pilot, was first developed on the Cierva C.19 Mk.V and saw production on the Cierva C.30 series of 1934.

Rotor drives initially took the form of a rope wrapped around the rotor axle and then pulled by a team of men to accelerate the rotor prior to a long taxi to bring the rotor up to speed sufficient for takeoff. The next innovation was a fully deflectable horizontal stabilizer that directed propeller slipstream into the rotor. Cierva license, Pitcairn-Cierva Autogiro Company of Willow Grove, PA, finally solved the problem with a light mechanical transmission driven by the engine.

The Groen Brothers Hawk 4 of the late 1992 is advertised as possessing Ultra-Short Take-Off and Landing (USTOL) capability, enabling the aircraft to take off and land within a very short distance (25 feet). This is merely a new name for performance autogyros have always possessed.

History

Juan de la Cierva, a Spanish engineer and aeronautical enthusiast, invented the first successful rotorcraft, which he named **autogiro** in 1923. His craft used a tractor-mounted forward propeller and engine, a rotor mounted on a mast, and a horizontal and vertical stabilizer. His first three designs, C.1, C.2, and C.3, were unstable due to aerodynamic and structural deficiencies in their rotors. His fourth design, the C.4, fitted with flapping hinges to attach each rotor blade to the hub, made the first successful flight of a rotary-wing aircraft, piloted by Alejandro Gomez Spencer, on 17 January 1923. The C.4 was fitted with conventional airplane ailerons, elevators and rudder for control. During a later test flight, the engine failed shortly after takeoff and the aircraft descended slowly and steeply to a safe landing, validating la Cierva's efforts to produce an aircraft that could be flown safely at low airspeeds.

Avro-built Cierva C.19 Mk.IV Autogiro, built in 1932. Cuatro Vientos Airport Museum, Madrid, Spain.

This success eventually became well known and after further limited Autogiro development in Spain, la Cierva accepted an offer from Scottish industrialist James G. Weir to establish the **Cierva Autogiro Company** in England following a 20 October 1925 demonstration to the British Air Ministry at Farnborough. Test pilot for these flights was Frank T. Courtney. From this point on, Britain became the world center of rotary-wing aircraft development.

A crash due to blade root failure in February 1927 led to an improvement in rotor hub design. Adjacent the flapping hinge a drag hinge was incorporated to allow each blade to slightly oscillate horizontally and relieve inplane stresses generated as a byproduct of flapping motion. Development work on means to accelerate the rotor prior to takeoff was also undertaken. Efforts with the C.11 in Spain showed that development of a light and efficient mechanical rotor transmission was not a trivial undertaking and led to the adoption of the intermediate expedient of inclining the horizontal stabilizer to redirect the propeller slipstream into the rotor while on the ground. This feature was later introduced on the production C.19 series of 1929.

Further Autogiro development led to the Cierva C.8 L.IV which on 18 September 1928 made the first rotary-wing aircraft crossing of the English Channel followed by an extensive tour of Europe. US industrialist Harold F. Pitcairn had in 1925 visited la Cierva in Spain upon learning of the successful flights of the Autogiro; in 1928 he visited la Cierva in England after taking a C.8 L.IV test flight piloted by Arthur H.C.A. Rawson and being particularly impressed with the Autogiro's safe vertical descent capability, purchased a C.8 L.IV with a **Wright Whirlwind** engine. Arriving in the United States on 11 December 1928 accompanied by Rawson, this Autogiro was redesignated C.8W.

(Further editing of the following to continue)

The Cierva "Autodynamic" rotor used drag hinges with offset axes to perform this to good effect with great simplicity, but the Pitcairn collective pitch control advanced the "jump" ability.

The C-19 technology was licensed to a number of manufacturers, including Harold Pitcairn in the U.S. (in 1928) and Focke-Achgelis of Germany. In 1931 Amelia Earhart flew a Pitcairn PCA-2 to a then world altitude record of 18,415 feet (5613 m).

In World War II, Germany pioneered a very small gyroglider "rotor-kite", the Focke-Achgelis Fa 330 "Bachstelze" (Water-wagtail), towed by submarines to provide aerial surveillance. It's reported that

German gyro pilots were often forgotten in the heat of battle when the submarine dived suddenly. The Japanese also developed the Kayaba Ka-1 Autogyro for reconnaissance, artillery-spotting, and anti-submarine uses.

The autogyro was resurrected post WW2 when Dr. Igor Bensen (a doctor of Divinity) saw a captured German U-Boat's gyroglider, and was fascinated by its characteristics. At work he was tasked with the analysis of the British "Rotachute" gyro glider designed by expatriate Austrian Raoul Hafner. This led him to adapt the design for his own purposes and eventually market the B-7.

Post WW2 autogyros, such as the Bensen B-8M gyrocopter, generally use a pusher configuration for simplicity and to increase visibility for the pilot. For greater simplicity, they generally lack both variable-pitch rotors and powered rotors. It must be noted that Bensen autogyros and its derivatives have established an abysmal safety record due to their deficient stability and control characteristics greatly worsened by use of a teetering rotor, and their marketing as a **build it yourself and teach yourself how to fly it** aircraft.

Three FAA-certified designs, **Umbaugh U-18/Air and Space 18A** of 1965, **Avian 2-180** of 1967, and **McCulloch J-2** or 1972 have for various reasons been commercial failures.

Bensen's design

The Bensen Gyrocopter™, the protoype of many post WW2 gyroplanes, actually consists of three versions, the B-6, B-7 and B-8. All three were designed in both unpowered and powered forms.

The basic design is a simple frame of square aluminum or galvanized steel tubing, reinforced with triangles of lighter tubing. It is arranged so that the stress falls on the tubes, or special fittings, not the bolts. All welds or soldered structural joints should be inspected.

The rotor is on the top of the vertical mast. The outlying fixed wheels are mounted on an axle (of tubing). The front-to-back keel (more tubing) mounts the forward wheel (which casters), seat, other tubes, engine and a vertical stabilizer. Some versions mount seaplane-style floats and successfully land and take off from water.

It is common for the vertical stabilizer to drag on the ground unless it is cut away. This is also why many frames have a small wheel mounted on the back end of the keel.

Many light gyroplane rotors are made from aluminum, though GRP-based composite blades (Sport Copter, Averso, Revolution, RAF eg) and GRP-skinned blades are increasing in number. Even aircraft-quality birch was specified in early Bensen designs, and a wood/steel composite is still used in the world speed record holding Wallis.

Flight Controls

There are only three flight controls: a control stick, rudder pedals and a throttle.

Modern designs typically use a between-legs control stick instead, and the precession is handled by a mechanical linkage so that left and right stick motions are more intuitive than Bensen's simple design.

Another control is a simple set of rudder pedals that move the hinged back half of the vertical stabilizer, similar to a rudder on a fixed wing aircraft. This lets the pilot keep the craft lined up in the desired direction of motion. The stabilizer is mounted behind the pusher propeller, so one can steer the craft on the ground and during takeoff. Some builders use a pushrod between the rudder bar and stabilizer. Others use cables.

Some simple autogyros, including Bensen's G-6, do not use controllable-vertical stabilizers at all. They are fixed - this works for towed gyro gliders, but not for powered gyros.

The throttle and choke are usually levers mounted where convenient- often under the seat.

The rotor generates more lift on the leading side and less on the lagging side, and this causes the rotor to tilt backwards with forward airspeed (helicopters tilt their rotor in the opposite way as they use their rotor to drag the vehicle through the air, whereas an autogyros's blades are unpowered). This increases drag and has a lot to do with the relatively low top speed that Autogyros can reach.

Flight characteristics

Autogyros are often regarded by fixed-wing aircraft pilots as "dangerously unstable", which is certainly true when its pilot is, as is so often the case, self-taught with no professional flight instruction received whatsoever. Piloted properly, a certificated autogyro is significantly safer than any other type of aircraft because it cannot stall, since the rotor of a autogyro is always spinning. If translational airspeed becomes zero, the autogyro will descend vertically to the ground, rotor still spinning. Though safe for the pilot and passengers, landing from a vertical descent usually results in damage to the autogyro.

One weakness in certain types of autogyro is pitch instability (pitch is the tilting up or down of the craft as viewed from the front or the back). Pitch instability can be a problem because autogyros lose rotor control authority in negative-G forces (positive-G forces push people into their seats; negative-G forces make people float out of them, such as driving over a hump back bridge at high speed in an automobile). Negative-G forces "unload the rotor" and rotor control authority is lost. A flying autogyro hangs from the rotor much like an object hung from a string. As long as the plane is hanging from the rotor, stability is maintained. The instant zero or negative-Gs are introduced, rotor speed begins to decay and the forces stabilizing the plane are lost.

Negative-Gs can be caused by Pilot-Induced Oscillation, or PIO. PIO happens when a pilot adjusts his pitch too much too quickly, then makes a countering control input to bring the pitch back. The countering input often overcompensates, and the autogyro begins to buck like a bronco. You can see a similar effect when some learner-drivers are doing kangaroo-hops in a car with a stick shift and clutch. This is most likely at higher engine throttle settings. If the pilot continues to fight the plane, the rotor (which is flexible) can slow down due to the lack of positive G force, and can flop down and strike the spinning propeller, which destroys both and sends the autogyro into an uncontrolled fall. The way to avoid this during an incipient PIO is to apply gentle back pressure on the stick (to raise the nose in pitch) and cut engine power. Note that this is the exact opposite of what fixed-wing pilots are trained to do when in trouble, which has led to some unfortunate accidents and the autogyro's undeserved reputation for being "dangerous."

Another danger is "bunting over" or a Power Push-Over (PPO). An autogyro's vertical airspeed (climb or sink rate) is directly coupled to airspeed. Increase forward airspeed, increase rate of climb. In order to maintain level flight at high engine throttle settings, the pilot must tilt the rotor forward to prevent climbing and maintain level flight. The rotor thus becomes more nearly horizontal, and the control stick becomes more sensitive.

Too much forward stick, and the autogyro's rotor can aim down towards the ground. When this happens, negative-Gs occur, rotor speed drops too low to provide lift, and a high-thrustline autogyro is then pitched forward by the propeller thrust and tumbles end-over-end in a somersault. It is virtually impossible to regain control after a full PPO.

Two factors can lead to pitch instability: no or too small horizontal stabilizers (h-stabs) on too short a tail and high thrustline propeller placement which destabilises the force diagram. A large h-stab, ideally in the prop wash (where the propeller blows on it) will reduce the tendency of an autogyro to bunt over as a result of improper control input by damping the control response.

If the propeller thrustline in an autogyro is high -- meaning the axis of propeller power is above the center of gravity for the aircraft -- the autogyro tends to pitch forward under sudden power application (see PPOs above, as for why this is Bad). (Unfortunately, Bensen-type autogyros have a notably high thrustline.) If the thrustline is low, the autogyro tends to pitch up under sudden power application, which is harmless. It's difficult to have a low thrustline without a really tall autogyro (such as a "Dominator" style) however, so most autogyro designs simply try to get the thrustline as low as possible though still being slightly above the center of gravity.

In spite of these dangers, most autogyros are designed to reduce them. Also, the majority of autogyro pilot training involves avoidance of PIO and PPOs.

Autogyro rotors usually feature a teeter-hinge in the middle. Picture a autogyro or helicopter from above, rotor spinning clockwise. If the aircraft is flying forward, the rotor tips on the left are traveling faster than the aircraft, while those on the right are actually going backwards relative to the craft. If the rotor blades were fixed, this would produce uneven lift -- more lift on the left side, since those blades are traveling faster. The teeter hinge on each blade lets it "flap" up and down. As the blade swings on the left, the increased speed makes it flap up with a greater angle of attack to the relative wind. This increases drag and reduces lift. As it swings to the right, it's now going slower, relative to forward speed. This reduced drag lets it flap down and get a better bite into the air, increasing lift.

Pitch is controlled by a conventional joystick coupled to the rotor. Pulling back on the stick tilts the rotor back, increasing lift and decreasing forward airspeed. Pushing forward on the stick decreases lift and increases airspeed, as long as it is not pushed much beyond horizontal (see PPO above). The plane's direction is controlled by rudder pedals.

Records and Application

As of 2002, Wing Commander Ken Wallis, an enthusiast who has built several gyroplanes, holds or has held most of the type's record performances. These include the speed record of 111.7mph (186km/h), and the straight-line distance record of 543.27 miles (905km). The record picture is continually changing, and on 16 November 2002, Ken Wallis increased the speed record to 207.7 km/h - and simultaneously set another world record as the oldest pilot to set a world record! See: [1]

Ken Wallis also built and flew one of the most famous autogyros - "Little Nellie" - in the James Bond movie "You Only Live Twice".

- Hours flown

  Autogyros are often used to herd range animals. An autogyro 'cowboy' holds the world record for total hours in the air each week.

The Bensen design has also been used by hobbyists, sight-seers and scientists (for game counting).

- Speed

  The CarterCopter fixed wing/autogyro hybrid has been unofficially flown in tests at speeds above 170 mph. The claimed *theoretical* top speed for this general design is in excess of 450 mph.
  In the late 1950s, the Fairey Rotodyne, another hybrid was capable of 213 mph.

Kits

Many autogyros are assembled from kits.

Kits with all parts, ready to assemble, are listed for US$19,550 as of 18th July 2002. This is *extremely* inexpensive for an aircraft. This includes an engine, the major expense. It can be reduced. Some people are clever at scrounging materials. However, scrounging increases one's construction time and program risk. Buying both the engine and rotor hub is recommended by most vendors.

Some people who actually completed an autogyro have said that it took them about a year, working in their spare time. Careful estimates place most build times at 100 to 200 hours.

Kit vendors often say that since it has relatively few parts, hobbyists can assemble it more rapidly and correctly than most fixed-wing kit aircraft. Kit vendors recommend working on it every day for an hour or two.

Warnings

Most vendors recommend that a new pilot have at least ten hours of instruction by a rated instructor in small fixed-wing aircraft, followed by at least two hours of instruction in a dual-place autogyro with an experienced instructor. An autogyro is more similar to a fixed-wing aircraft than to a helicopter. One must be able to land safely and reliably before attempting to fly any aircraft alone.

Autogyros are relatively safe, but not foolproof. There were 19 fatal autogyro accidents reported to the FAA between 1996 and 2001. Autogyros are aircraft. Do not neglect safety precautions: training, instrumentation, flight rules, preflight checklists and periodic inspections and maintenance. In the United States private, recreational, and commercial pilot licenses with rotorcraft category and gyroplane class rating are issued, or the rating is added to an existing license for other aircraft; holders of sport pilot licenses can also qualify to fly autogyros. Requirements include completing required training times, passing written exams, and successfully doing oral and practical tests. Sport pilot license in-flight tests can be conducted in single-seat aircraft, but a "single place only" limitation is placed on the certificate in such cases.

"Learning to fly the rotor" is a vital ingredient for safe flight in an autogyro - models and rotary kites can help the learning process, and towed gyro-gliders and boom-trainers are ideal tools for this as well as being cheap to build and fly