

All About
Helicopters

(Types, Components & Equipments)



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Chapter- 1

Introduction to Helicopter



A **helicopter** is a type of rotorcraft in which lift and thrust are supplied by one or more engine driven rotors. In contrast with fixed-wing aircraft, this allows the helicopter to take off and land vertically, to hover, and to fly forwards, backwards and laterally. These attributes allow helicopters to be used in congested or isolated areas where fixed-wing aircraft would not be able to take off or land. The capability to efficiently hover for extended periods of time allows a helicopter to accomplish tasks that fixed-wing aircraft and other forms of vertical takeoff and landing aircraft cannot perform.

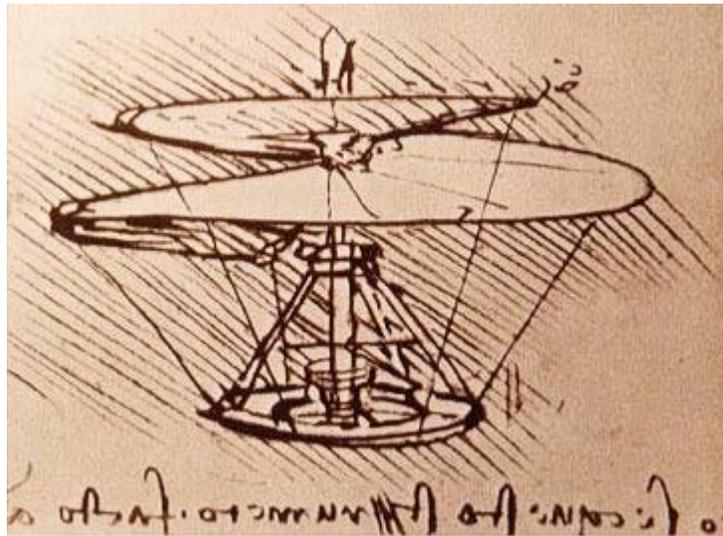
The word 'helicopter' is adapted from the French *hélicoptère*, coined by Gustave de Ponton d'Amecourt in 1861, which originates from the Greek *helix/helik-* (ἑλῖξ) = "twisted, curved" and *pteron* (πτερόν) = "wing".

Helicopters were developed and built during the first half-century of flight, with the Focke-Wulf Fw 61 being the first operational helicopter in 1936. Some helicopters reached limited production, but it was not until 1942 that a helicopter designed by Igor Sikorsky reached full-scale production, with 131 aircraft built. Though most earlier designs used more than one main rotor, it was the single main rotor with antitorque tail rotor configuration of this design that would come to be recognized worldwide as *the helicopter*.

History

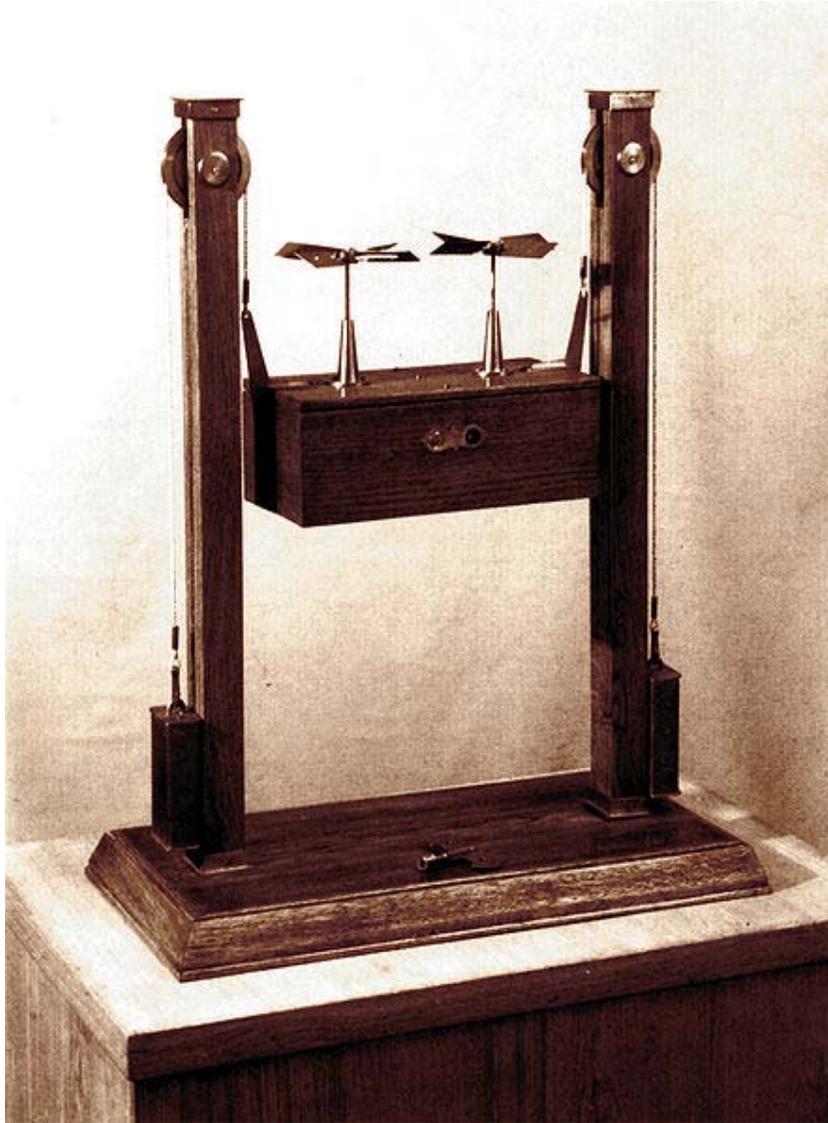
The earliest references for vertical flight have come from China. Since around 400 BC, Chinese children have played with bamboo flying toys, and the 4th-century AD Daoist book *Baopuzi* (抱朴子 "Master who Embraces Simplicity") reportedly describes some of the ideas inherent to rotary wing aircraft:

“ Someone asked the master about the principles of mounting to dangerous heights and traveling into the vast inane. The Master said, "Some have made flying cars with wood from the inner part of the jujube tree, using ox-leather [straps] fastened to returning blades so as to set the machine in motion." ”



da Vinci's "aerial screw"

It was not until the early 1480s, when Leonardo da Vinci created a design for a machine that could be described as an "aerial screw", that any recorded advancement was made towards vertical flight. His notes suggested that he built small flying models, but there were no indications for any provision to stop the rotor from making the whole craft rotate. As scientific knowledge increased and became more accepted, men continued to pursue the idea of vertical flight. Many of these later models and machines would more closely resemble the ancient bamboo flying top with spinning wings, rather than Da Vinci's screw.



Prototype created by M. Lomonosov, 1754

In July 1754, Mikhail Lomonosov demonstrated a small coaxial rotor to the Russian Academy of Sciences. It was powered by a spring and suggested as a method to lift meteorological instruments. In 1783, Christian de Launoy, and his mechanic, Bienvenu, made a model with a pair of counter-rotating rotors, using turkey flight feathers as rotor blades, and in 1784, demonstrated it to the French Academy of Sciences. Sir George Cayley, influenced by a childhood fascination with the Chinese flying top, grew up to develop a model of feathers, similar to Launoy and Bienvenu, but powered by rubber bands. By the end of the century, he had progressed to using sheets of tin for rotor blades and springs for power. His writings on his experiments and models would become influential on future aviation pioneers. Alphonse Pénaud would later develop coaxial rotor model helicopter toys in 1870, also powered by rubber bands. One of these toys, given as a gift by their father, would inspire the Wright brothers to pursue the dream of flight.

In 1861, the word "helicopter" was coined by Gustave de Ponton d'Amécourt, a French inventor who demonstrated a small, steam-powered model. While celebrated as an innovative use of a new metal, aluminum, the model never lifted off the ground. D'Amecourt's linguistic contribution would survive to eventually describe the vertical flight he had envisioned. Steam power was popular with other inventors as well. In 1878 Enrico Forlanini's unmanned helicopter was also powered by a steam engine. It was the first of its type that rose to a height of 12 meters (40 ft), where it hovered for some 20 seconds after a vertical take-off. Emmanuel Dieuaide's steam-powered design featured counter-rotating rotors powered through a hose from a boiler on the ground.

In 1885, Thomas Edison was given US\$1,000 by James Gordon Bennett, Jr., to conduct experiments towards developing flight. Edison built a helicopter and used the paper for a stock ticker to create guncotton, with which he attempted to power an internal combustion engine. The helicopter was damaged by explosions and one of his workers was badly burned. Edison reported that it would take a motor with a ratio of three to four pounds per horsepower produced to be successful, based on his experiments. Ján Bahýľ, a Slovak inventor, adapted the internal combustion engine to power his helicopter model that reached a height of 0.5 meters (1.6 ft) in 1901. On 5 May 1905, his helicopter reached four meters (13 ft) in altitude and flew for over 1,500 meters (4,900 ft). In 1908, Edison patented his own design for a helicopter powered by a gasoline engine with box kites attached to a mast by cables for a rotor, but it never flew.

First flights



Paul Cornu's helicopter in 1907

In 1906, two French brothers, Jacques and Louis Breguet, began experimenting with airfoils for helicopters and in 1907, those experiments resulted in the *Gyroplane No. 1*. Although there is some uncertainty about the dates, sometime between 14 August and 29 September 1907, the Gyroplane No. 1 lifted its pilot up into the air about two feet (0.6 m) for a minute. However, the Gyroplane No. 1 proved to be extremely unsteady and required a man at each corner of the airframe to hold it steady. For this reason, the flights of the Gyroplane No. 1 are considered to be the first manned flight of a helicopter, but not a free or untethered flight.

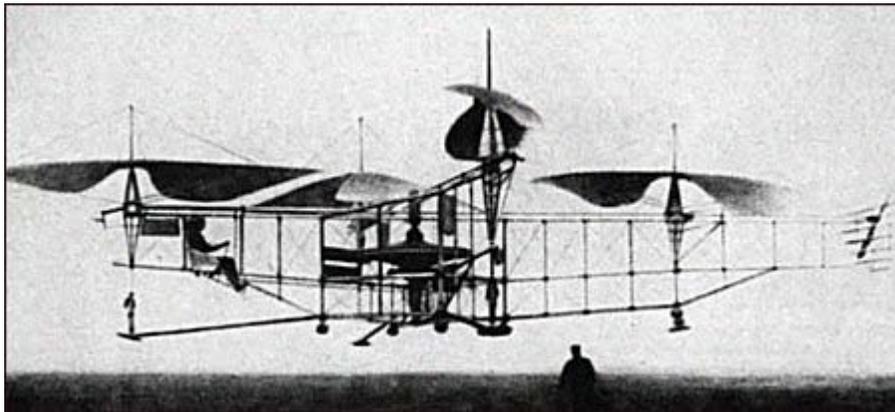
That same year, fellow French inventor Paul Cornu designed and built a Cornu helicopter that used two 20-foot (6 m) counter-rotating rotors driven by a 24-hp (18-kW) Antoinette engine. On 13 November 1907, it lifted its inventor to 1 foot (0.3 m) and remained aloft

for 20 seconds. Even though this flight did not surpass the flight of the Gyroplane No. 1, it was reported to be the first truly free flight with a pilot. Cornu's helicopter would complete a few more flights and achieve a height of nearly 6.5 feet (2 m), but it proved to be unstable and was abandoned.

The Danish inventor Jacob Ellehammer built the Ellehammer helicopter in 1912. It consisted of a frame equipped with two contra-rotating discs, each of which was fitted with six vanes around its circumference. After a number of indoor tests, the aircraft was demonstrated outdoors and made a number of free take-offs. Experiments with the helicopter continued until September 1916, when it tipped over during take-off, destroying its rotors.

Early development

In the early 1920s, Argentine Raúl Pateras Pescara, while working in Europe, demonstrated one of the first successful applications of cyclic pitch. Coaxial, contra-rotating, biplane rotors could be warped to cyclically increase and decrease the lift they produced. The rotor hub could also be tilted forward a few degrees, allowing the aircraft to move forward without a separate propeller to push or pull it. Pescara was also able to demonstrate the principle of autorotation, by which helicopters safely land after engine failure. By January 1924, Pescara's helicopter No. 3 could fly for up ten minutes.



Oehmichen N°2 1922

One of Pescara's contemporaries, Frenchman Etienne Oehmichen, set the first helicopter world record recognized by the *Fédération Aéronautique Internationale* (FAI) on 14 April 1924, flying his helicopter 360 meters (1,181 ft). On 18 April 1924, Pescara beat Oehmichen's record, flying for a distance of 736 meters (nearly a half mile) in 4 minutes and 11 seconds (about 8 mph, 13 km/h) maintaining a height of six feet (2 m). Not to be outdone, Oehmichen reclaimed the world record on 4 May when he flew his No. 2 machine again for a 14-minute flight covering 5,550 feet (1.05 mi, 1.69 km) while climbing to a height of 50 feet (15 m). Oehmichen also set the 1 km closed-circuit record at 7 minutes 40 seconds.

In the USA, George de Bothezat built the quadrotor De Bothezat helicopter for the United States Army Air Service but the Army cancelled the program in 1924, and the aircraft was scrapped.

Meanwhile, Juan de la Cierva was developing the first practical rotorcraft in Spain. In 1923, the aircraft that would become the basis for the modern helicopter rotor began to take shape in the form of an autogyro, Cierva's C.4. Cierva had discovered aerodynamic and structural deficiencies in his early designs that could cause his autogyros to flip over after takeoff. The flapping hinges that Cierva designed for the C.4 allowed the rotor to develop lift equally on the left and right halves of the rotor disk. A crash in 1927, led to the development of a drag hinge to relieve further stress on the rotor from its flapping motion. These two developments allowed for a stable rotor system, not only in a hover, but in forward flight.

Albert Gillis von Baumhauer, a Dutch aeronautical engineer, began studying rotorcraft design in 1923. His first prototype "flew" ("hopped" and hovered in reality) on 24 September 1925, with Dutch Army-Air arm Captain Floris Albert van Heijst at the controls. The controls that Captain van Heijst used were Von Baumhauer's inventions, the cyclic and collective. Patents were granted to von Baumhauer for his cyclic and collective controls by the British ministry of aviation on 31 January 1927, under patent number 265,272.

In 1928, Hungarian aviation engineer Oszkár Asbóth constructed a helicopter prototype that took off and landed at least 182 times, with a maximum single flight duration of 53 minutes.

In 1930, the Italian engineer Corradino D'Ascanio built his D'AT3, a coaxial helicopter. His relatively large machine had two, two-bladed, counter-rotating rotors. Control was achieved by using auxiliary wings or servo-tabs on the trailing edges of the blades, a concept that was later adopted by other helicopter designers, including Bleeker and Kaman. Three small propellers mounted to the airframe were used for additional pitch, roll, and yaw control. The D'AT3 held modest FAI speed and altitude records for the time, including altitude (18 m or 59 ft), duration (8 minutes 45 seconds) and distance flown (1,078 m or 3,540 ft).

In the Soviet Union, Boris N. Yuriev and Alexei M. Cheremukhin, two aeronautical engineers working at the *Tsentralniy Aerogidrodinamicheskii Institut* (TsAGI, Russian: Центральный аэрогидродинамический институт (ЦАГИ), English: *Central Aerohydrodynamic Institute*), constructed and flew the TsAGI 1-EA single rotor helicopter, which used an open tubing framework, a four blade main rotor, and twin sets of 1.8-meter (6-foot) diameter anti-torque rotors; one set of two at the nose and one set of two at the tail. Powered by two M-2 powerplants, up-rated copies of the Gnome Monosoupape rotary radial engine of World War I, the TsAGI 1-EA made several successful low altitude flights. By 14 August 1932, Cheremukhin managed to get the 1-EA up to an unofficial altitude of 605 meters (1,985 ft), shattering d'Ascanio's earlier

achievement. As the Soviet Union was not yet a member of the FAI, however, Cheremukhin's record remained unrecognized.

Nicolas Florine, a Russian engineer, built the first twin tandem rotor machine to perform a free flight. It flew in Sint-Genesius-Rode, at the *Laboratoire Aérotechnique de Belgique* (now von Karman Institute) in April 1933, and attained an altitude of six meters (20 ft) and an endurance of eight minutes. Florine chose a co-rotating configuration because the gyroscopic stability of the rotors would not cancel. Therefore the rotors had to be tilted slightly in opposite directions to counter torque. Using hingeless rotors and co-rotation also minimised the stress on the hull. At the time, it was one of the most stable helicopter in existence.

The Bréguet-Dorand *Gyroplane Laboratoire* was built in 1933. After many ground tests and an accident, it first took flight on 26 June 1935. Within a short time, the aircraft was setting records with pilot Maurice Claisse at the controls. On 14 December 1935, he set a record for closed-circuit flight with a 500-meter (1,600 ft) diameter. The next year, on 26 September 1936, Claisse set a height record of 158 meters (520 ft). And, finally, on 24 November 1936, he set a flight duration record of one hour, two minutes and 5 seconds over a 44 kilometer (27 mi) closed circuit at 44.7 kilometers per hour (27.8 mph). The aircraft was destroyed in 1943 by an Allied airstrike at Villacoublay airport.

Birth of an industry



First airmail service by helicopter in Los Angeles, 1947

Despite the success of the *Gyroplane Laboratoire*, the German Focke-Wulf Fw 61, first flown in 1936, would eclipse its accomplishments. The Fw 61 broke all of the helicopter world records in 1937, demonstrating a flight envelope that had only previously been achieved by the autogyro. Nazi Germany would use helicopters in small numbers during World War II for observation, transport, and medical evacuation. The Flettner Fl 282 *Kolibri* synchropter was used in the Mediterranean, while the Focke Achgelis Fa 223 *Drache* was used in Europe. Extensive bombing by the Allied forces prevented Germany from producing any helicopters in large quantities during the war.

In the United States, Igor Sikorsky and W. Lawrence LePage were competing to produce the United States military's first helicopter. Prior to the war, LePage had received the patent rights to develop helicopters patterned after the Fw 61, and built the XR-1. Meanwhile, Sikorsky had settled on a simpler, single rotor design, the VS-300. After experimenting with configurations to counteract the torque produced by the single main rotor, he settled on a single, smaller rotor mounted vertically on the tailboom.

Developed from the VS-300, Sikorsky's R-4 became the first mass produced helicopter with a production order for 100 aircraft. The R-4 was the only Allied helicopter to see service in World War II, primarily being used for rescue in Burma, Alaska, and other areas with harsh terrain. Total production would reach 131 helicopters before the R-4 was replaced by other Sikorsky helicopters such as the R-5 and the R-6. In all, Sikorsky would produce over 400 helicopters before the end of World War II.

As LePage and Sikorsky were building their helicopters for the military, Bell Aircraft hired Arthur Young to help build a helicopter using Young's semi-rigid, teetering-blade rotor design, which used a weighted stabilizing bar. The subsequent Model 30 helicopter showed the design's simplicity and ease of use. The Model 30 was developed into the Bell 47, which became the first helicopter certificated for civilian use in the United States. Produced in several countries, the Bell 47 would stand as the most popular helicopter model for nearly 30 years.

Turbine age

In 1951, at the urging of his contacts at the Department of the Navy, Charles Kaman modified his K-225 helicopter with a new kind of engine, the turboshaft engine. This adaptation of the turbine engine provided a large amount of power to the helicopter with a lower weight penalty than piston engines, with their heavy engine blocks and auxiliary components. On 11 December 1951, the Kaman K-225 became the first turbine-powered helicopter in the world. Two years later, on 26 March 1954, a modified Navy HTK-1, another Kaman helicopter, became the first twin-turbine helicopter to fly. However, it was the Sud Aviation Alouette II that would become the first helicopter to be produced with a turbine-engine.

Reliable helicopters capable of stable hover flight were developed decades after fixed-wing aircraft. This is largely due to higher engine power density requirements than fixed-wing aircraft. Improvements in fuels and engines during the first half of the 20th century

were a critical factor in helicopter development. The availability of lightweight turboshaft engines in the second half of the 20th century led to the development of larger, faster, and higher-performance helicopters. While smaller and less expensive helicopters still use piston engines, turboshaft engines are the preferred powerplant for helicopters today.

Uses

Due to the operating characteristics of the helicopter—its ability to takeoff and land vertically, and to hover for extended periods of time, as well as the aircraft's handling properties under low airspeed conditions—it has been chosen to conduct tasks that were previously not possible with other aircraft, or were time- or work-intensive to accomplish on the ground. Today, helicopter uses include transportation, construction, firefighting, search and rescue, and military uses.



Sikorsky S-64 Skycrane lifting a prefab house



Kern County (California) Fire Department Bell 205 dropping water on fire



A British Westland WAH-64 Apache attack helicopter



HH-65 Dolphin demonstrating hoist rescue capability



A Sikorsky S-76C+ air ambulance being loaded by firefighters



RAF Westland Sea King for rescue of people in distress around the United Kingdom

A helicopter used to carry loads connected to long cables or slings is called an aerial crane. Aerial cranes are used to place heavy equipment, like radio transmission towers and large air conditioning units, on the tops of tall buildings, or when an item must be raised up in a remote area, such as a radio tower raised on the top of a hill or mountain. Helicopters are used as aerial cranes in the logging industry to lift trees out of terrain where vehicles cannot travel and where environmental concerns prohibit the building of roads. These operations are referred to as longline because of the long, single sling line used to carry the load.

Helitack is the use of helicopters to combat wildland fires. The helicopters are used for aerial firefighting (or water bombing) and may be fitted with tanks or carry helibuckets. Helibuckets, such as the Bambi bucket, are usually filled by submerging the bucket into lakes, rivers, reservoirs, or portable tanks. Tanks fitted onto helicopters are filled from a hose while the helicopter is on the ground or water is siphoned from lakes or reservoirs through a hanging snorkel as the helicopter hovers over the water source. Helitack helicopters are also used to deliver firefighters, who rappel down to inaccessible areas, and to resupply firefighters. Common firefighting helicopters include variants of the Bell 205 and the Erickson S-64 Aircrane helitanker.

Helicopters are used as air ambulances for emergency medical assistance in situations when an ambulance cannot easily or quickly reach the scene. Helicopters are also used when a patient needs to be transported between medical facilities and air transportation is the most practical method for the safety of the patient. Air ambulance helicopters are

equipped to provide medical treatment to a patient while in flight. The use of helicopters as an air ambulance is often referred to as MEDEVAC, and patients are referred to as being "airlifted", or "medevaced".

Police departments and other law enforcement agencies use helicopters to pursue suspects. Since helicopters can achieve a unique aerial view, they are often used in conjunction with police on the ground to report on suspects' locations and movements. They are often mounted with lighting and heat-sensing equipment for night pursuits.

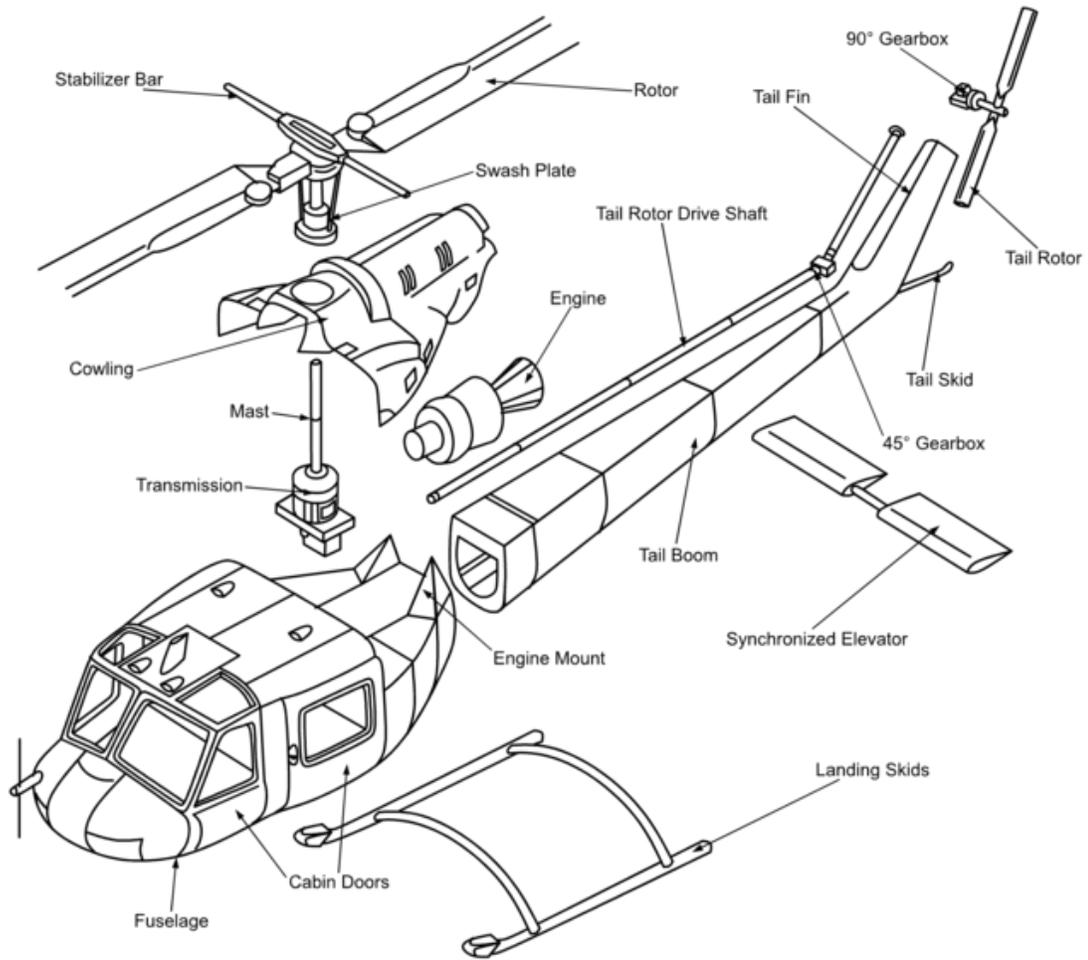
Military forces use attack helicopters to conduct aerial attacks on ground targets. Such helicopters are mounted with missile launchers and miniguns. Transport helicopters are used to ferry troops and supplies where the lack of an airstrip would make transport via fixed-wing aircraft impossible. The use of transport helicopters to deliver troops as an attack force on an objective is referred to as Air Assault. Unmanned Aerial Systems (UAS) helicopter systems of varying sizes are being developed by companies for military reconnaissance and surveillance duties. Naval forces also use helicopters equipped with dipping sonar for anti-submarine warfare, since they can operate from small ships.

Oil companies charter helicopters to move workers and parts quickly to remote drilling sites located out to sea or in remote locations. The speed over boats makes the high operating cost of helicopters cost effective to ensure that oil platforms continue to flow. Various companies specialize in this type of operation.

Other uses of helicopters include, but are not limited to:

- Aerial photography
- Motion picture photography
- Electronic news gathering
- Reflection seismology
- Search and Rescue
- Tourism or recreation
- Transport

Design features



Basic anatomy of a Helicopter

Antitorque configurations



MD Helicopters 520N NOTAR

Most helicopters have a single main rotor, but torque created as the engine turns the rotor against its air drag causes the body of the helicopter to turn in the opposite direction to the rotor. To eliminate this effect, some sort of antitorque control must be used. The design that Igor Sikorsky settled on for his VS-300 was a smaller rotor mounted vertically on the tail. The tail rotor pushes or pulls against the tail to counter the torque effect, and has become the recognized convention for helicopter design. Some helicopters utilize alternate antitorque controls in place of the tail rotor, such as the ducted fan (called *Fenestron* or *FANTAIL*), and NOTAR. NOTAR provides antitorque similar to the way a wing develops lift, through the use of a Coandă effect on the tailboom.

The use of two or more horizontal rotors turning in opposite directions is another configuration used to counteract the effects of torque on the aircraft without relying on an antitorque tail rotor. This allows the power normally required to drive the tail rotor to be applied to the main rotors, increasing the aircraft's lifting capacity. Primarily, there are three common configurations that use the counterrotating effect to benefit the rotorcraft. Tandem rotors are two rotors with one mounted behind the other. Coaxial rotors are two rotors that are mounted one above the other with the same axis. Intermeshing rotors are two rotors that are mounted close to each other at a sufficient angle to allow the rotors to

intermesh over the top of the aircraft. Transverse rotors is another configuration found on tiltrotors and some earlier helicopters, where the pair of rotors are mounted at each end of the wings or outrigger structures. Tip jet designs permit the rotor to push itself through the air, and avoid generating torque.

Engines

The number, size and type of engine used on a helicopter determines the size, function and capability of that helicopter design. The earliest helicopter engines were simple mechanical devices, such as rubber bands or spindles, which relegated the size of helicopters to toys and small models. For a half century before the first airplane flight, steam engines were used to forward the development of the understanding of helicopter aerodynamics, but the limited power did not allow for manned flight. The introduction of the internal combustion engine at the end of the 19th century became the watershed for helicopter development as engines began to be developed and produced that were powerful enough to allow for helicopters able to lift humans.

Early helicopter designs utilized custom-built engines or rotary engines designed for airplanes, but these were soon replaced by more powerful automobile engines and radial engines. The single, most-limiting factor of helicopter development during the first half of the 20th century was that the amount of power produced by an engine was not able to overcome the engine's weight in vertical flight. This was overcome in early successful helicopters by using the smallest engines available. When the compact, flat engine was developed, the helicopter industry found a lighter-weight powerplant easily adapted to small helicopters, although radial engines continued to be used for larger helicopters.

Turbine engines revolutionized the aviation industry, and the turboshaft engine finally gave helicopters an engine with a large amount of power and a low weight penalty. The turboshaft engine was able to be scaled to the size of the helicopter being designed, so that all but the lightest of helicopter models are powered by turbine engines today.

Special jet engines developed to drive the rotor from the rotor tips are referred to as tip jets. Tip jets powered by a remote compressor are referred to as cold tip jets, while those powered by combustion exhaust are referred to as hot tip jets. An example of a cold jet helicopter is the Sud-Ouest Djinn, and an example of the hot tip jet helicopter is the YH-32 Hornet.

Some radio-controlled helicopters and smaller, helicopter-type unmanned aerial vehicles, use electric motors. Radio-controlled helicopters may also have piston engines that use fuels other than gasoline, such as Nitromethane. Some turbine engines commonly used in helicopters can also use biodiesel instead of jet fuel.

Flight conditions

There are two basic flight conditions for a helicopter; hover and forward flight.



Helicopter hovering over boat in rescue exercise

- **Hover**
Hovering is the most challenging part of flying a helicopter. This is because a helicopter generates its own gusty air while in a hover, which acts against the fuselage and flight control surfaces. The end result is constant control inputs and corrections by the pilot to keep the helicopter where it is required to be. Despite the complexity of the task, the control inputs in a hover are simple. The cyclic is used to eliminate drift in the horizontal plane, that is to control forward and back, right and left. The collective is used to maintain altitude. The pedals are used to control nose direction or heading. It is the interaction of these controls that makes hovering so difficult, since an adjustment in any one control requires an adjustment of the other two, creating a cycle of constant correction.
- **Forward flight**
In forward flight a helicopter's flight controls behave more like that in a fixed-wing aircraft. Displacing the cyclic forward will cause the nose to pitch down, with a resultant increase in airspeed and loss of altitude. Aft cyclic will cause the nose to pitch up, slowing the helicopter and causing it to climb. Increasing collective (power) while maintaining a constant airspeed will induce a climb while decreasing collective will cause a descent. Coordinating these two inputs, down collective plus aft cyclic or up collective plus forward cyclic, will result in airspeed changes while maintaining a constant altitude. The pedals serve the same function in both a helicopter and a fixed-wing aircraft, to maintain balanced flight.

This is done by applying a pedal input in whichever direction is necessary to center the ball in the turn and bank indicator.

Safety

Limitations



HAL Dhruv performing aerobatics during the Royal International Air Tattoo in 2008



Royal Australian Navy Squirrel helicopters during a display at the 2008 Melbourne Grand Prix

The main limitation of the helicopter is its low speed. There are several reasons a helicopter cannot fly as fast as a fixed wing aircraft. When the helicopter is hovering, the outer tips of the rotor travel at a speed determined by the length of the blade and the RPM. In a moving helicopter, however, the speed of the blades relative to the air depends on the speed of the helicopter as well as on their rotational velocity. The airspeed of the advancing rotor blade is much higher than that of the helicopter itself. It is possible for this blade to exceed the speed of sound, and thus produce vastly increased drag and vibration.

Because the advancing blade has higher airspeed than the retreating blade and generates a dissymmetry of lift, rotor blades are designed to "flap" – lift and twist in such a way that the advancing blade flaps up and develops a smaller angle of attack. Conversely, the retreating blade flaps down, develops a higher angle of attack, and generates more lift. At high speeds, the force on the rotors is such that they "flap" excessively and the retreating blade can reach too high an angle and stall. For this reason, the maximum safe forward airspeed of a helicopter is given a design rating called V_{NE} , *Velocity, Never Exceed*. In addition, at extremely high speeds, it is possible for the helicopter to travel faster than the retreating blade which would inevitably stall the blade, regardless of the angle of attack.

During the closing years of the 20th century designers began working on helicopter noise reduction. Urban communities have often expressed great dislike of noisy aircraft, and police and passenger helicopters can be unpopular. The redesigns followed the closure of

some city heliports and government action to constrain flight paths in national parks and other places of natural beauty.

Helicopters also vibrate; an unadjusted helicopter can easily vibrate so much that it will shake itself apart. To reduce vibration, all helicopters have rotor adjustments for height and weight. Blade height is adjusted by changing the pitch of the blade. Weight is adjusted by adding or removing weights on the rotor head and/or at the blade end caps. Most also have vibration dampers for height and pitch. Some also use mechanical feedback systems to sense and counter vibration. Usually the feedback system uses a mass as a "stable reference" and a linkage from the mass operates a flap to adjust the rotor's angle of attack to counter the vibration. Adjustment is difficult in part because measurement of the vibration is hard, usually requiring sophisticated accelerometers mounted throughout the airframe and gearboxes. The most common blade vibration adjustment measurement system is to use a stroboscopic flash lamp, and observe painted markings or coloured reflectors on the underside of the rotor blades. The traditional low-tech system is to mount coloured chalk on the rotor tips, and see how they mark a linen sheet. Gearbox vibration most often requires a gearbox overhaul or replacement. Gearbox or drive train vibrations can be extremely harmful to a pilot. The most severe being pain, numbness, loss of tactile discrimination and dexterity.

Deadliest crashes

1. 2002: A Mil Mi-26 was shot down over Chechnya; 127 killed.
2. 1997: An Israeli CH-53 crashed in Israel; 73 killed.
3. December 14, 1992: Georgian forces in Abkhazia shot down a Russian Army Mi-8 by SA-14 MANPADs with the loss of three crew members and 58 passengers, mainly Russian refugees.
4. October 4, 1993: A Georgian Mi-8 was shot down while transporting 60 refugees from eastern Abkhazia.
5. May 10, 1977: An Israeli CH-53 crashed near Yitav in the Jordan Valley; 54 killed.
6. September 11, 1982: A U.S. Army CH-47 Chinook crashed at an air show in Mannheim, Germany; 46 killed.
7. 1986: A British International Helicopters Boeing 234LR Chinook crashed in the Shetland Islands; 45 killed.
8. 1992 Azerbaijani Mil Mi-8 shootdown: 44 killed.
9. 2009 Pakistan Army Mil Mi-17 crash: 41 killed.
10. January 26, 2005: An USMC CH-53E crashed near Ar Rutbah, Iraq killing all 31 service members onboard.

World records

Record type	Record	Helicopter	Pilot(s)	Date	Location	Note
Speed	400.87 km/h	Westland Lynx	John Trevor Egginton	11 August 1986	England	

Distance without landing	3,561.55 km	Hughes YOH-6A	Robert G. Ferry (USA)	6 April 1966	USA	
Around-the-world speed	136.7 km/h	Agusta A109S Grand	Scott Kasprowicz (USA)	August 2008	From and to New York via Europe, Russia, Alaska, Canada	No in-flight refueling
Highest level flight altitude	11,010 m	Sikorsky CH-54 Tarhe	James K. Church	4 Nov 1971	USA	
Altitude with 40-tonne payload	2,255 m	Mil V-12	Vasily Kolochenko et al	6 Aug 1969	Soviet Union	

Chapter- 2

Helicopter Rotor



The rotor head of a Sikorsky S-92

A **helicopter main rotor** or **rotor system** is a type of fan that is used to generate both the aerodynamic lift force that supports the weight of the helicopter, and thrust which counteracts aerodynamic drag in forward flight. Each main rotor is mounted on a vertical mast over the top of the helicopter, as opposed to a helicopter tail rotor, which is connected through a combination a drive shaft(s) and gearboxes along the tail boom. A helicopter's rotor is generally made up of two or more rotor blades. The blade pitch is typically controlled by a swashplate connected to the helicopter flight controls.

Helicopter rotor diameters are relatively large, as this gives much better energy and propellant efficiency for the speeds at which helicopters fly.

History and development



Bundesarchiv, Bild 102-12440
Foto: o.Ang. | Oktober 1931

Helicopter rotor of Engelbert Zaschka, German master engineer, 1931, image from the German Federal Archives

Before the development of powered helicopters in the mid 20th century, autogyro pioneer Juan de la Cierva researched and developed many of the fundamentals of the rotor. Cierva is credited with successful development of multi-bladed, fully articulated rotor systems. This type of system is widely used today in many multi-bladed helicopters.

In the 1930s, Arthur Young improved the stability of two-bladed rotor systems with the introduction of a stabilizer bar. This system was used in several Bell and Hiller helicopter models. It is also used in many remote control model helicopters.

Design

A helicopter rotor is powered by the engine, through the transmission, to the rotating mast. The mast is a cylindrical metal shaft which extends upward from—and is driven by—the transmission. At the top of the mast is the attachment point for the rotor blades called the hub. The rotor blades are then attached to the hub. Main rotor systems are classified according to how the main rotor blades are attached and move relative to the main rotor hub. There are three basic classifications: rigid, semirigid, or fully articulated, although some modern rotor systems use an engineered combination of these classifications.

Unlike the small diameter fans used in turbofan jet engines, the main rotor on a helicopter has a quite large diameter, permitting a large quantity of air to be accelerated. This permits a lower downwash velocity for a given amount of thrust. As it is more efficient at low speeds to accelerate a large amount of air by a small degree than a small amount of air by a large degree it greatly increases the aircraft's energy efficiency and this reduces the fuel use and permits reasonable range.

Parts and functions



The simple rotor of a Robinson R22



Robinson R44 rotor head

The simple rotor of a Robinson R22 showing (from the top):

- The following are driven by the link rods from the rotating part of the swashplate.
 - Pitch hinges, allowing the blades to twist about the axis extending from blade root to blade tip.
- Teeter hinge, allowing one blade to rise vertically while the other falls vertically. This motion occurs whenever translational relative wind is present, or in response to a cyclic control input.
- Scissor link and counterweight, carries the main shaft rotation down to the upper swashplate
- Rubber covers protect moving and stationary shafts
- Swashplates, transmitting cyclic and collective pitch to the blades (the top one rotates)
- Three non-rotating control rods transmit pitch information to the lower swashplate
- Main mast leading down to main gearbox

Swash plate

The pitch of main rotor blades can be varied cyclically throughout its rotation in order to control the direction of rotor thrust vector (the part of the rotor disc where the maximum thrust will be developed, front, rear, right side, etc.). Collective pitch is used to vary the magnitude of rotor thrust (increasing or decreasing thrust over the whole rotor disc at the same time). These blade pitch variations are controlled by tilting and/or raising or lowering the swash plate with the flight controls. The vast majority of helicopters maintain a constant rotor speed (RPM) during flight, leaving only the angle of attack of the blades as the sole means of adjusting thrust from the rotor.

The swash plate is two concentric disks or plates, one plate rotates with the mast, connected by idle links, while the other does not rotate. The rotating plate is also connected to the individual blades through pitch links and pitch horns. The non-rotating plate is connected to links which are manipulated by pilot controls, specifically, the collective and cyclic controls.

The swash plate can shift vertically and tilt. Through shifting and tilting, the non-rotating plate controls the rotating plate, which in turn controls the individual blade pitch.

Fully articulated

Juan de la Cierva developed the fully articulating rotor for the autogyro, and it is the basis of his design that permitted successful helicopter development. In a fully articulated rotor system, each rotor blade is attached to the rotor hub through a series of hinges which allow the blade to move independently of the others. These rotor systems usually have three or more blades. The blades are allowed to flap, feather, and lead or lag independently of each other. The horizontal hinge, called the flapping hinge, allows the blade to move up and down. This movement is called flapping and is designed to compensate for dissymmetry of lift. The flapping hinge may be located at varying

distances from the rotor hub, and there may be more than one hinge. The vertical hinge, called the lead-lag or drag hinge, allows the blade to move back and forth. This movement is called lead-lag, dragging, or hunting. Dampers are usually used to prevent excess back and forth movement around the drag hinge. The purpose of the drag hinge and dampers is to compensate for the acceleration and deceleration caused by momentum conservation, and not by Coriolis Effect. Each blade can also be feathered, that is, rotated around its spanwise axis. Feathering the blade means changing the pitch angle of the blade. By changing the pitch angle of the blades the thrust and direction of the main rotor disc can be controlled. An example of this type of rotor system is the Agusta AW109 series of aircraft; later models have switched from a traditional bearing system to an Elastomeric bearing based system.

Rigid

The term "rigid rotor" usually refers to a hingeless rotor system with blades flexibly attached to the hub. The two basic types of rigid rotor include the Reiseler-Kreiser feathering system and the Lockheed flapping system. The Reiseler-Kreiser feathering rigid rotor was developed and tested on a series of gyroplanes sponsored by E.B. Wilford in Pennsylvania. Irven Culver of Lockheed developed one of the first flapping rigid rotors and was tested and developed on a series of helicopters in the 1960s and 1970s. In a flapping rigid rotor system, each blade flaps, drags, and feathers (depending on the design) about flexible sections of the root. The flapping rigid rotor system is mechanically simpler than the fully articulated rotor system. Loads from flapping and lead/lag forces are accommodated by bending rather than through hinges. By flexing, the blades themselves compensate for the forces which previously required rugged hinges. The result is a rotor system that has less lag in the control response, because the rotor has much less oscillation. The rigid rotor system also negates the danger of mast bumping inherent in semi-rigid rotors. The rigid rotor can also be called a hingeless rotor. Developed most notably for the XH-51 high speed and AH-56 Cheyenne attack compound helicopter, the rotors simplified aerobatic maneuvers at high speeds, but proved troublesome to perfect on the AH-56, and would never be produced in large numbers or adopted by other helicopter makers.

However, to completely contradict the previous statement, flapping rigid rotors have long been standard equipment on the Bolkow series of helicopters, as well as models produced by Aerospatiale, AgustaWestland, and MD helicopters.

Semirigid



Semirigid rotor system

The semirigid rotor can also be referred to as a teetering or seesaw rotor. This system is normally composed of two blades which meet just under a common flapping, or teetering hinge at the rotor shaft. This allows the blades to flap together in opposite motions like a seesaw. This underslinging of the blades below the teetering hinge, combined with an adequate dihedral or coning angle on the blades, minimizes variations in the radius of each blade's center of mass from the axis of rotation as the rotor turns, which in turn reduces the stress on the blades from lead and lag forces caused by coriolis effect. Secondary flapping hinges may also be provided to provide sufficient flexibility to minimize bouncing. Feathering is accomplished by the feathering hinge at the blade root, which allows changes to the pitch angle of the blade. The most widespread implementations of this system are the Bell 206/OH-58 series of aircraft and the Robinson R22 series.

Stabilizer bar

A number of engineers, among them Arthur M. Young in the U.S., and Dieter Schlüter in Germany, found that flight stability for helicopters could be achieved with a stabilizer bar or flybar. The stabilizer bar has weighted ends which cause the bar to stay relatively stable in the plane of rotation. Through mechanical linkages, the stable rotation of the bar

is mixed with the swashplate movement so that internal (steering) as well as external (wind) forces on the rotor are dampened. This eases the workload of the pilot to maintain control of the aircraft. Stanley Hiller arrived at a similar method to improve stability by adding short stubby airfoils, or paddles, at each end; However, Hiller's "Rotomatic" system was also used to deliver cyclic control inputs to the main rotor as a sort of control rotor, the paddles provided the added stability by dampening the effects of external forces on the rotor.

In fly-by-wire helicopters or RC models, a microcontroller with gyroscopes and a venturi sensor can replace the stabilizer. This *flybar-less* design has the advantage of easy reconfiguration and fewer mechanical parts.

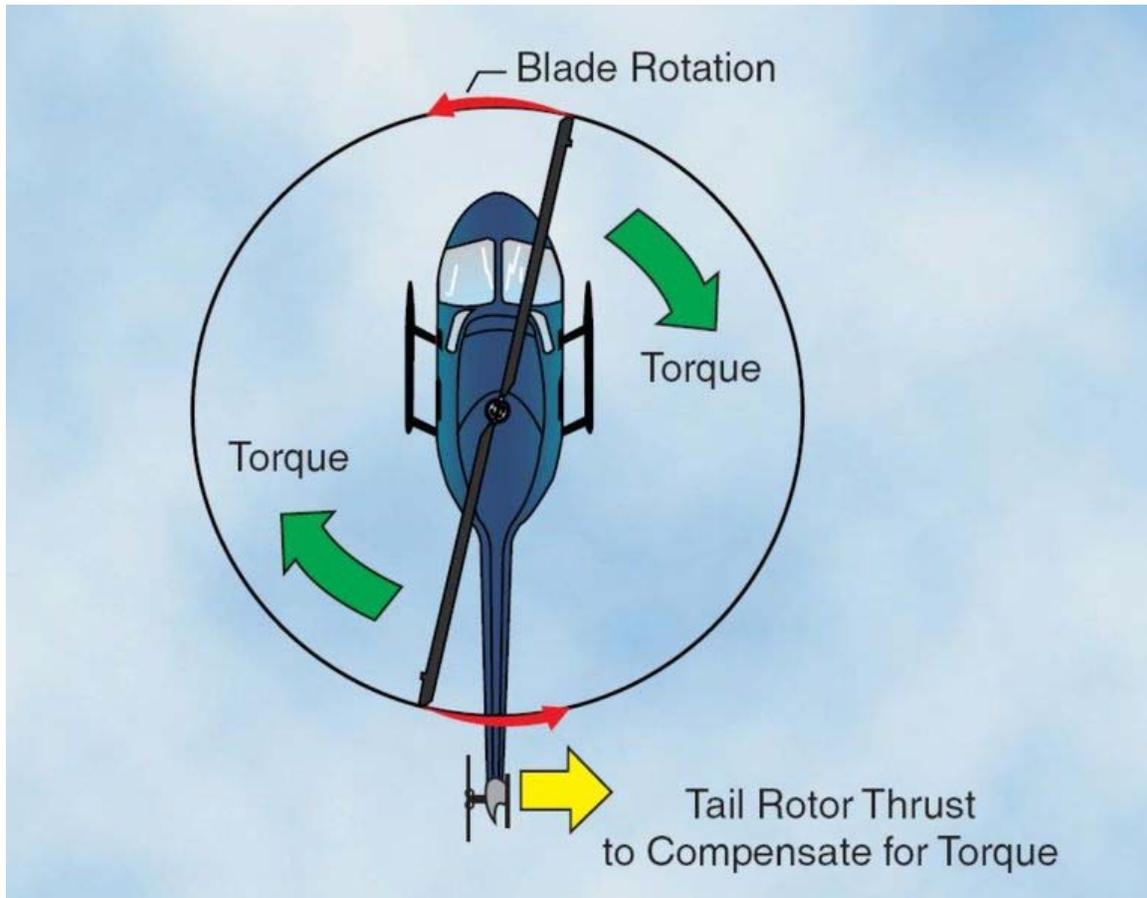
Combination

Modern rotor systems may use the combined principles of the rotor systems mentioned above. Some rotor hubs incorporate a flexible hub, which allows for blade bending (flexing) without the need for bearings or hinges. These systems, called "flextures", are usually constructed from composite material. Elastomeric bearings may also be used in place of conventional roller bearings. Elastomeric bearings are bearings constructed from a rubber type material and have limited movement that is perfectly suited for helicopter applications. Flextures and elastomeric bearings require no lubrication and, therefore, require less maintenance. They also absorb vibration, which means less fatigue and longer service life for the helicopter components. Examples include Bell 407, Bell 430, Eurocopter A-Star(AS350)/Twin-Star(AS355) and arguably MD Helicopters (Formerly Hughes 500), this model has externally mounted lead-lag dampeners {which makes it more of a hingeless fully articulated hub}.

Rotor configurations

Most helicopters have a single, main rotor but require a separate rotor to overcome torque. This is accomplished through a variable pitch, antitorque rotor or tail rotor. This is the design that Igor Sikorsky settled on for his VS-300 helicopter and it has become the recognized convention for helicopter design, although designs do vary. When viewed from above, the main rotors of helicopter designs from Germany, United Kingdom and the United States rotate counter-clockwise, all others rotate clockwise. This can make it difficult when discussing aerodynamic effects on the main rotor between different designs, since the effects may manifest on opposite sides of each aircraft.

Single main rotor



Antitorque: Torque effect on a helicopter

With a single main rotor helicopter, the creation of torque as the engine turns the rotor creates a torque effect that causes the body of the helicopter to turn in the opposite direction of the rotor. To eliminate this effect, some sort of antitorque control must be used, with a sufficient margin of power available to allow the helicopter to maintain its heading and provide yaw control. The three most common controls used today are the traditional *tail rotor*, Eurocopter's *Fenestron* (also called a *fantail*), and MD Helicopters' *NOTAR*.

Tail rotor



Tail rotor of an SA 330 Puma

The tail rotor is a smaller rotor mounted so that it rotates vertically or near-vertically at the end of the tail of a traditional single-rotor helicopter. The tail rotor's position and distance from the center of gravity allow it to develop thrust in a direction opposite of the main rotor's rotation, to counter the torque effect created by the main rotor. Tail rotors are simpler than main rotors since they require only collective changes in pitch to vary thrust. The pitch of the tail rotor blades is adjustable by the pilot via the anti-torque pedals, which also provide directional control by allowing the pilot to rotate the helicopter around its vertical axis (thereby changing the direction the craft is pointed).

Ducted fan



Fenestron on a EC 120B

Fenestron and FANTAIL are trademarks for a ducted fan mounted at the end of the tail boom of the helicopter and used in place of a tail rotor. Ducted fans have between eight and 18 blades arranged with irregular spacing, so that the noise is distributed over different frequencies. The housing is integral with the aircraft skin and allows a high rotational speed, therefore a ducted fan can have a smaller size than a conventional tail rotor.

The Fenestron was used for the first time at the end of the 1960s on the second experimental model of Sud Aviation's SA 340, and produced on the later model Aérospatiale SA 341 Gazelle. Besides Eurocopter and its predecessors, a ducted fan tail rotor was also used on the canceled military helicopter project, the United States Army's RAH-66 Comanche, as the FANTAIL.

NOTAR

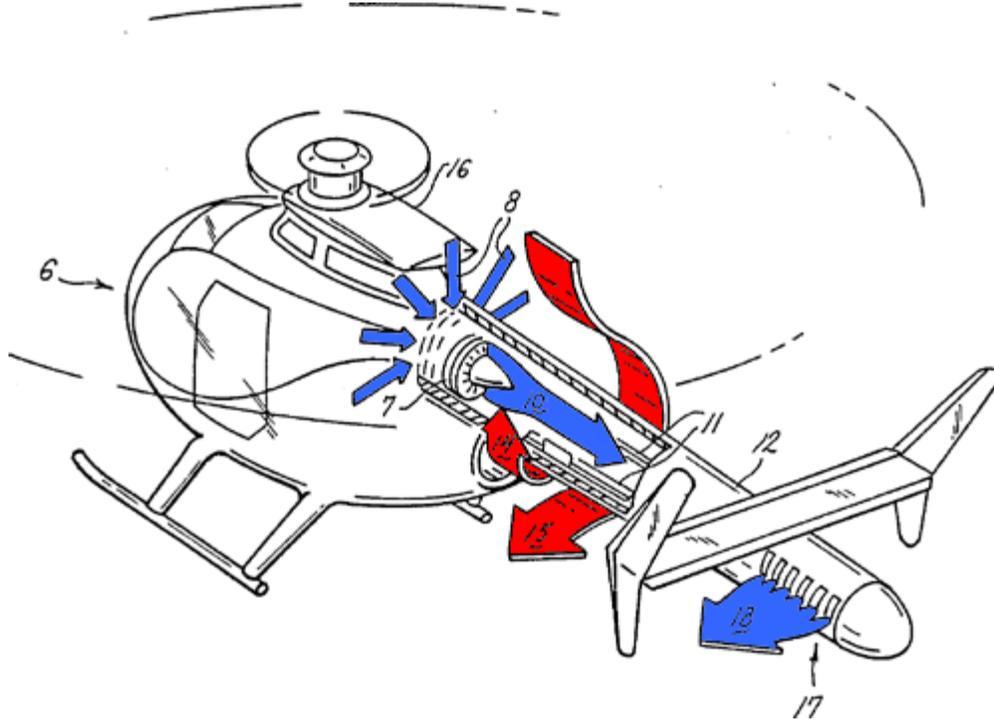


Diagram showing the movement of air through the NOTAR system

NOTAR, an acronym for *NO Tail Rotor*, is a helicopter anti-torque system that eliminates the use of the tail rotor on a helicopter. Although the concept took some time to refine, the NOTAR system is simple in theory and works to provide antitorque the same way a wing develops lift using the Coandă effect. A variable pitch fan is enclosed in the aft fuselage section immediately forward of the tail boom and driven by the main rotor transmission. This fan forces low pressure air through two slots on the right side of the tailboom, causing the downwash from the main rotor to hug the tailboom, producing lift, and thus a measure of antitorque proportional to the amount of airflow from the rotorwash. This is augmented by a direct jet thruster (which also provides directional yaw control) and vertical stabilizers.

Development of the NOTAR system dates back to 1975 when engineers at Hughes Helicopters began concept development work. In December 1981 Hughes flew a OH-6A fitted with NOTAR for the first time. A more heavily modified prototype demonstrator first flew in March 1986 and successfully completed an advanced flight-test program, validating the system for future application in helicopter design. There are currently three production helicopters that incorporate the NOTAR design, all produced by MD Helicopters. This antitorque design also improves safety by eliminating the possibility of personnel walking into the tail rotor.

Tip jets

Another single main rotor configuration without a tail rotor is the tip jet rotor, where the main rotor is not driven by the mast, but from nozzles on the rotor blade tips; which are either pressurized from a fuselage-mounted gas turbine or have their own turbojet, ramjet or rocket thrusters. Although this method is simple and eliminates torque, the prototypes that have been built are less fuel efficient than conventional helicopters and produced more noise. The Percival P.74 was underpowered and was not able to achieve flight, while the Hiller YH-32 Hornet had good lifting capability but performed poorly otherwise. Other aircraft relied on supplemental thrust so that the tipjets could be shut down and the rotor could autorotate after the fashion of an autogyro. The experimental Fairey Jet Gyrodyne and 40-seat Fairey Rotodyne passenger prototype were evaluated to have flown very well using this method. Perhaps the most unusual design of this type was the Rotary Rocket Roton ATV, which was originally envisioned to take off utilizing a rocket-tipped rotor. No tip jet rotorcraft have ever entered into production.

Dual rotors (counterrotating)

Counterrotating rotors are rotorcraft configurations with a pair or more of large horizontal rotors turning in opposite directions to counteract the effects of torque on the aircraft without relying on an antitorque tail rotor. This allows the power normally required to drive the tail rotor to be applied to the main rotors, increasing the aircraft's lifting capacity. Primarily, there are three common configurations that use the counterrotating effect to benefit the rotorcraft. Tandem rotors are two rotors with one mounted behind the other. Coaxial rotors are two rotors that are mounted one above the other with the same axis. Intermeshing rotors are two rotors that are mounted close to each other at a sufficient angle to allow the rotors to intermesh over the top of the aircraft. Another configuration found on tiltrotors and some earlier helicopters is called transverse rotors where the pair of rotors are mounted at each end of wing-type structures or outriggers.

Tandem



CH-47 Chinook

Tandem rotors are two horizontal main rotor assemblies mounted one behind the other. Tandem rotors achieve pitch attitude changes to accelerate and decelerate the helicopter through a process called differential collective pitch. To pitch forward and accelerate, the rear rotor increases collective pitch, raising the tail and the front rotor decreases collective pitch, simultaneously dipping the nose. To pitch upward while decelerating (or moving rearward), the front rotor increases collective pitch to raise the nose and the rear rotor decreases collective pitch to lower the tail. Yaw control is developed through opposing cyclic pitch in each rotor; to pivot right, the front rotor tilts right and the rear rotor tilts left, and to pivot left, the front rotor tilts left and the rear rotor tilts right. All of the rotor power contributes to lift, and it is simpler to handle changes in the center of gravity fore-aft. However, it requires the expense of two large rotors rather than the more common one large main rotor and a much smaller tail rotor. The CH-47 Chinook is the most common tandem rotor helicopter today.

Coaxial



Kamov Ka-50 of the Russian Air Force, with coaxial rotors

Coaxial rotors are a pair of rotors mounted one above the other on the same shaft and turning in opposite directions. The advantage of the coaxial rotor is that, in forward flight, the lift provided by the advancing halves of each rotor compensates for the retreating half of the other, eliminating one of the key effects of dissymmetry of lift: retreating blade stall. However, other design considerations plague coaxial rotors. There is an increased mechanical complexity of the rotor system because it requires linkages and swashplates for two rotor systems. Add that each rotor system needs to be turned in opposite directions means that the mast itself is more complex, and provisions for making pitch changes to the upper rotor system must pass through the lower rotor system.

Intermeshing



HH-43 Huskie

Intermeshing rotors on a helicopter are a set of two rotors turning in opposite directions, with each rotor mast mounted on the helicopter with a slight angle to the other so that the blades intermesh without colliding. This configuration is sometimes referred to as a synchropter. Intermeshing rotors have high stability and powerful lifting capability. The arrangement was successfully used in Nazi Germany for a small anti-submarine warfare helicopter, the Flettner Fl 282 Kolibri. During the Cold War, the American company, Kaman Aircraft produced the HH-43 Huskie for the USAF firefighting and rescue missions. The latest Kaman model, the Kaman K-MAX, is a dedicated sky crane design.

Transverse



Mi-12

Transverse rotors are mounted on the end of wings or outriggers, perpendicular to the body of the aircraft. Similar to tandem rotors and intermeshing rotors, the transverse rotor also uses differential collective pitch. But like the intermeshing rotors, the transverse rotors use the concept for changes in the roll attitude of the rotorcraft. This configuration is found on two of the first viable helicopters, the Focke-Wulf Fw 61 and the Focke-Achgelis Fa 223, as well as the world's largest helicopter ever built, the Mil Mi-12. It is also the configuration found on tiltrotors, such the Bell XV-15 and the newer Bell-Boeing V-22 Osprey.

Quadrotor



De Bothezat Quadrotor, 1923

A quadrotor helicopter has four rotors in an "X" configuration designated as front-left, front-right, rear-left, and rear-right. Rotors to the left and right are in a transverse configuration while those in the front and to the rear are in a tandem configuration.

The main attraction of quadrotors is their mechanical simplicity—a quadrotor helicopter using electric motors and fixed-pitch rotors uses only four moving parts.

Blade design

The blades of a helicopter are long, narrow airfoils with a high aspect ratio, a shape which minimises drag from tip vortices. They generally contain a degree of washout to reduce the lift generated at the tips, where the airflow is fastest and vortex generation would be a significant problem. Rotor blades are made out of various materials, including aluminium, composite structure and steel or titanium with abrasion shields along the leading edge. Rotorcraft blades are traditionally passive, but research into active blade control trailing edge flaps is performed.

Limitations and hazards

Helicopters with teetering rotors, for example the two-blade system on the Bell, Robinson and others, must not be subjected to a low-g condition because such rotor systems do not control the fuselage attitude. This can result in the fuselage assuming an attitude controlled by momentum and tail rotor thrust that causes the tail boom to intersect the main rotor tip-path plane, or result in the blade roots contacting the main rotor drive shaft causing the blades to separate from the hub (mast bumping).

Abrasion in sandy environments

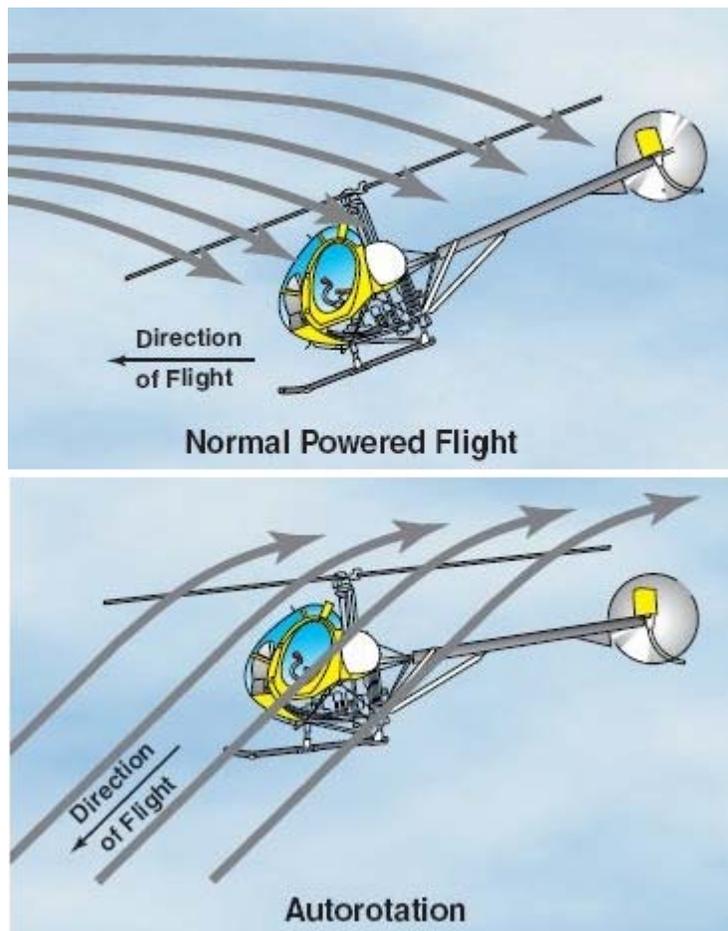
When operating in sandy environments, sand hitting the moving rotor blades erodes their surface. This can damage the rotors; the erosion also presents serious and costly maintenance problems.

The abrasion strips on helicopter rotor blades are made of metal, often titanium or nickel, which are very hard, but less hard than sand. When a helicopter is flown near to the ground in desert environments abrasion occurs from the sand striking the rotor blade. At night, the sand hitting the metal abrasion strip causes a visible corona or halo around the rotor blades. The corona effect is caused by the oxidation of eroded particles resulting in visible corona.

In 2009, war correspondent Michael Yon referred to this corona effect as "Kopp-Etchells effect", to honor Cpl. Benjamin Kopp, and Cpl. Joseph Etchells, recently fallen American and British soldiers, respectively.

Chapter- 3

Autoration



Airflow through a rotor

Autoration is the state of flight where the main rotor system of a helicopter is being turned by the action of air moving up through the rotor rather than engine power driving the rotor. The term *autoration* can be traced back to a period of early development in helicopters between 1915 and 1920 and refers to the rotors turning without the engine.

In normal, powered flight, air is drawn into the main rotor system from above and exhausted downward, but during autorotation, air moves up into the rotor system from

below as the helicopter descends. Autorotation is permitted mechanically because of a freewheeling unit, which allows the main rotor to continue turning even if the engine is not running. It is the means by which a helicopter can be landed safely in the event of complete engine failure. Consequently all single-engine helicopters must demonstrate this capability in order to obtain a type certificate.

The longest autorotation in history was performed by Jean Boulet in 1972 when he reached a record altitude of 12,440m (40,814 ft) in an Aérospatiale Lama. Because of a -63°C temperature at that altitude, the engine flamed out and could not be restarted as soon as he reduced power. By using autorotation he was able to land the aircraft safely.

Descent and landing

For a helicopter, "autorotation" refers to the descending maneuver where the engine is disengaged from the main rotor system and the rotor blades are driven solely by the upward flow of air through the rotor. The *freewheeling unit* is a special clutch mechanism that disengages anytime the engine rpm is less than the rotor rpm. If the engine fails, the freewheeling unit automatically disengages the engine from the main rotor allowing the main rotor to rotate freely.

The most common reason for an autorotation is an engine malfunction or failure, but autorotations can also be performed in the event of a complete tail rotor failure or following loss of tail-rotor effectiveness, since there is virtually no torque produced in an autorotation. In some extreme situations, autorotations may also be used to recover from settling with power, if the aircraft's altitude permits. In all cases, a successful landing depends on the helicopter's height and velocity at the commencement of autorotation.

At the instant of engine failure, the main rotor blades are producing lift and thrust from their angle of attack and velocity. By immediately lowering collective pitch, which must be done in case of an engine failure, the pilot reduces lift and drag and the helicopter begins an immediate descent, producing an upward flow of air through the rotor system. This upward flow of air through the rotor provides sufficient thrust to maintain rotor rpm throughout the descent. Since the tail rotor is driven by the main rotor transmission during autorotation, heading control is maintained as in normal flight.

Several factors affect the rate of descent in autorotation: density altitude, gross weight, rotor rpm, and airspeed. The pilot's primary control of the rate of descent is airspeed. Higher or lower airspeeds are obtained with the cyclic pitch control just as in normal flight. Rate of descent is high at zero airspeed and decreases to a minimum at approximately 50 to 60 knots, depending upon the particular helicopter and the factors previously mentioned. As the airspeed increases beyond that which gives minimum rate of descent, the rate of descent increases again.

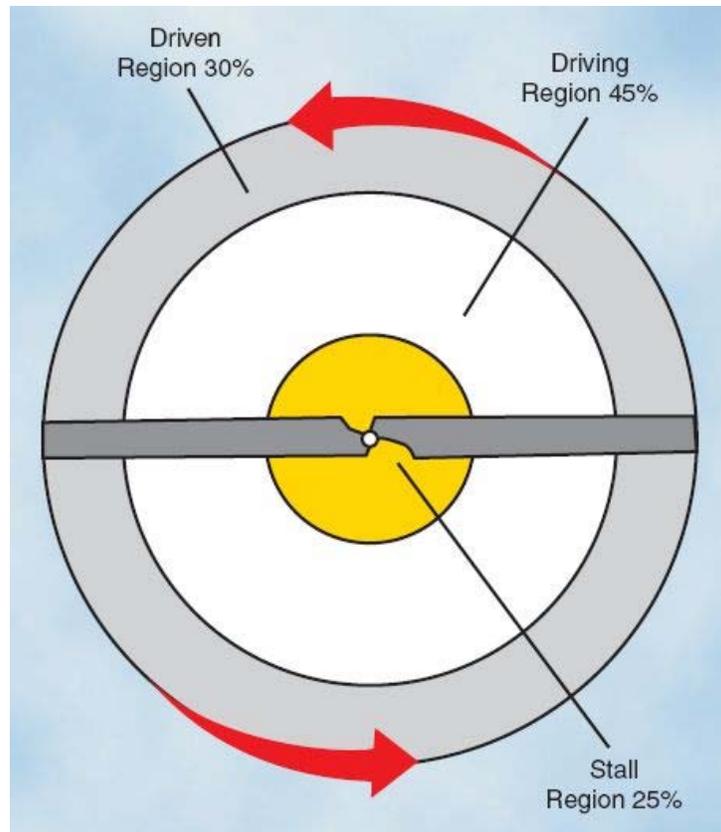
When landing from an autorotation, the energy stored in the rotating blades is used to decrease the rate of descent and make a soft landing. A greater amount of rotor energy is required to stop a helicopter with a high rate of descent than is required to stop a

helicopter that is descending more slowly. Therefore, autorotative descents at very low or very high airspeeds are more critical than those performed at the minimum rate of descent airspeed.

Each type of helicopter has a specific airspeed at which a power-off glide is most efficient. The best airspeed is the one which combines the greatest glide range with the slowest rate of descent. The specific airspeed is somewhat different for each type of helicopter, yet certain factors affect all configurations in the same manner. The specific airspeed for autorotations is established for each type of helicopter on the basis of average weather and wind conditions and normal loading.

A helicopter operated with heavy loads in high density altitude or gusty wind conditions can achieve best performance from a slightly increased airspeed in the descent. At low density altitude and light loading, best performance is achieved from a slight decrease in normal airspeed. Following this general procedure of fitting airspeed to existing conditions, the pilot can achieve approximately the same glide angle in any set of circumstances and estimate the touchdown point.

Autorotational regions



Blade regions in vertical autorotation descent

During vertical autorotation, the rotor disc is divided into three regions—the driven region, the driving region, and the stall region. The size of these regions vary with the blade pitch, rate of descent, and rotor rpm. When changing autorotative rpm, blade pitch, or rate of descent, the size of the regions change in relation to each other.

The driven region, also called the propeller region, is the region at the end of the blades. Normally, it consists of about 30 percent of the radius. It is the driven region that produces the most drag. The overall result is a deceleration in the rotation of the blade.

The driving region, or autorotative region, normally lies between 25 to 70 percent of the blade radius, which produces the forces needed to turn the blades during autorotation. Total aerodynamic force in the driving region is inclined slightly forward of the axis of rotation, producing a continual acceleration force. This inclination supplies thrust, which tends to accelerate the rotation of the blade. Driving region size varies with blade pitch setting, rate of descent, and rotor rpm.

The inner 25 percent of the rotor blade is referred to as the stall region and operates above its maximum angle of attack (stall angle) causing drag which tends to slow rotation of the blade. A constant rotor rpm is achieved by adjusting the collective pitch so blade acceleration forces from the driving region are balanced with the deceleration forces from the driven and stall regions.

By controlling the size of the driving region, the pilot can adjust autorotative rpm. For example, if the collective pitch is raised, the pitch angle increases in all regions. This causes the point of equilibrium to move inboard along the blade's span, thus increasing the size of the driven region. The stall region also becomes larger while the driving region becomes smaller. Reducing the size of the driving region causes the acceleration force of the driving region and rpm to decrease.

Chapter- 4

Amphibious Helicopter



An HH-3F Pelican helicopter of the United States Coast Guard lands on the water near a burning boat.

An **amphibious helicopter** is a helicopter that is intended to rest and take off from either land or water. Amphibious helicopters are used for a variety of specialized purposes including air-sea rescue, marine salvage and oceanography, in addition to other tasks that can be accomplished with any non-amphibious helicopter. An amphibious helicopter can be designed with a waterproof or water-resistant hull like a flying boat or it can be fitted with utility floats in the same manner as a floatplane.

Development

Helicopters have taken a primary role in air-sea rescue since their introduction in the 1940s. Helicopters can fly in rougher weather than fixed-wing aircraft, and they can deliver injured passengers directly to hospitals or other emergency facilities. A practical amphibious helicopter first appeared in 1941 and the water-landing feature soon proved

its worth. Non-amphibious helicopters were required to hover above the scene of a water accident and utilize a hoist but amphibious helicopters were capable of setting down on the water to effect a rescue more directly.

Fitted floats



A Vought-Sikorsky VS-300 experimental helicopter equipped with pontoons in 1941

In 1941, Igor Sikorsky fitted utility floats (also called pontoons) to the Vought-Sikorsky VS-300, making the first practical amphibious helicopter. In the 1940s and 1950s, some models of helicopter such as the Bell 47 and 48 and the Sikorsky R-4 and R-6 were fitted with utility floats so that they could rest on both water and land.

Pontoons can be filled with air or they can be utilized for storage of fuel or supplies. In 1949, Sikorsky produced the H-5H with both wheels and pontoons.

Boat hull design

The Sikorsky S-62 Seaguard was the first amphibious helicopter made with a flying boat hull—the prototype flew in 1958. Utilizing many components of the earlier S-55, the S-62 proved the idea, and Sikorsky flew their S-61 Sea King prototype in 1959 for the U.S. Navy, a model intended for anti-submarine warfare. Both the S-62 and S-61 were ready for delivery in 1961. Sikorsky produced 1100 S-61s, including some that were not watertight: a longer cargo-carrying version was given rear doors and a ramp. Sikorsky licensed other manufacturers such as Agusta, Mitsubishi and Westland to produce variants of the S-61.



An Italian SH-3 Sea King shows its boat hull, outrigger floats and wheeled landing gear

Amphibious helicopters came into their own in the 1960s when robust boat-hulled designs were produced in quantity for military and civilian operators. Amphibious helicopters paid dividends for rescue personnel who enjoyed greater safety and success during operations. Overwater operations that used non-amphibious helicopters relied to a higher degree on hoists, rescue baskets, and rescue swimmers. Nevertheless, beginning in the 1970s, amphibious models were steadily replaced by helicopter models unable to land on water, because of high amphibious aircraft development costs. The last amphibious helicopter model used by the United States Coast Guard was the Sikorsky HH-3F Pelican, retired in 1994.

Resting on the surface of the water with the rotor stopped, in conditions of brisk wind and mounting surface waves, a boat-hulled helicopter with stabilizing floats on either side is less likely to remain upright than a non-boat helicopter fitted with utility pontoons. Difficulty in lifting off can be encountered, especially when heavily loaded or in increasing seas.

Presidential helicopter



Army One carried four U.S. presidents

A series of helicopters have been used to transport the President of the United States, beginning in 1957. The helicopters, designated Army One or Marine One depending on the military arm operating them, were changed to the boat-hulled Sikorsky VH-3 Sea King in 1961. Beginning in 1989, the amphibious model was phased out in favor of the Sikorsky VH-60N Whitehawk.

Limited water capability

Helicopters can be designed to withstand limited contact with the surface of a body of water. The 1958 Vertol HUP-2 was an amphibious development of the twin-rotor Piasecki H-25 which strengthened its hull and replaced lower nose windows with tough aluminum. The HUP-2 was provided with a pair of stabilizing outrigger floats positioned amidships. The HUP-2 was able to taxi forward or backward on water, regardless of wind direction.

The CH-46 Sea Knight and its Canadian variant, the CH-113 Labrador, can land on water and rest for up to two hours in calm water. The rear sponsons hold two of the three landing gear units as well as self-sealing fuel tanks. The helicopter began service with the United States Marine Corps in 1962, and with the Canadian military in 1963, and is used to carry cargo and combat troops.



A Vertol HUP Retriever lands on water

The Boeing CH-47 Chinook was made sufficiently watertight to allow it to land on water for a short time in carrying out covert operations and special military missions. Buoyancy was increased with sealed compartments inside sponsons which extended most of the way along each side of the fuselage. For extended water usage, Boeing offered a kit to enhance its water resistance. The Sikorsky CH-53 Sea Stallion, first introduced in 1966, is also capable of landing on water for a limited time.

Boat-hulled helicopters



A Ryan Firebee drone is retrieved by a Sikorsky SH-3 Sea King helicopter

- 1961 – Sikorsky S-62
- 1961 – Sikorsky SH-3 Sea King
 - 1961 – Sikorsky S-61
 - 1965 – Sikorsky HH-3F Pelican
 - 1969 – Westland Sea King
- 1966 - Aérospatiale Super Frelon
- 1975 – Mil Mi-14 "Haze"
- 1982 – Kamov Ka-27

Chapter- 5

Aérospatiale Gazelle

SA 341/SA 342 Gazelle



Gazelle SA 342M of the French Army's Light Aviation (ALAT), Army's Helicopters Squadron (EHADT)

Role	Utility helicopter/Attack helicopter
Manufacturer	Aérospatiale Westland Aircraft SOKO
First flight	7 April 1967 (SA.340)
Introduced	1973
Status	Active
Primary users	French Army British Army Serbian Air Force Egyptian air force
Number built	1775?
Developed from	Aérospatiale Alouette III

The **Aérospatiale Gazelle** is a French-designed helicopter, created by the company Sud Aviation, which later became Aérospatiale.

Design and development

The Aérospatiale Gazelle originated in a French Army requirement for a lightweight utility helicopter. The design quickly attracted British interest, leading to a development and production share out agreement with British company Westland Helicopters. The

deal, signed in February 1967, allowed the production in Britain of 292 Gazelles and 48 Aérospatiale Pumas ordered by the British armed forces, in return Aérospatiale were given a work share in the manufacturing programme for the 40 Westland Lynx naval helicopters for the French Navy.

Though the general layout resembles that of the Alouette series, the Gazelle featured several important innovations. This was the first helicopter to carry a fenestron or fantail, which allows considerable noise reduction. Also, the rotor blades were made of composite materials, a feature now widely used in modern helicopters.

In service with the French Army Light Aviation, the ALAT, the Gazelle is used primarily as an anti-tank gunship (**SA 342M**) armed with HOT missiles. A light support version equipped with a 20 mm cannon is used (**SA 341F**) as well as anti-air variants carrying the Mistral air-to-air missile (**Gazelle Celtic** based on the **SA 341F**, **Gazelle Mistral** based on the **SA 342M**). The latest anti-tank and reconnaissance versions carry the Viviane thermal imagery system and so are called **Gazelle Viviane**. The Gazelle is being replaced in frontline duties by the Eurocopter Tiger but will continue to be used for light transport and liaison roles.

It also served with all branches of the British armed forces—the Royal Air Force, Royal Navy (including Royal Marines) and the British Army in a variety of roles. Four versions of the Gazelle were used by the British Forces. The **SA.341D** became the **Gazelle HT.3** in RAF service, equipped as a helicopter pilot trainer (hence HT). The **SA 341E** was used by the RAF for communications duties and VIP transport as the **Gazelle HCC.4**. The **SA 341C** was purchased as the **Gazelle HT.2** pilot trainer for the Royal Navy. The training variants have now been replaced by the Squirrel HT1. The **SA 341B** was equipped to a specification for the Army Air Corps as the **Gazelle AH.1** (from Army Helicopter Mark 1). It was used as an Air Observation Post (AOP) for directing artillery fire, Airborne Forward Air Controller (ABFAC) directing ground-attack aircraft, casualty evacuation, liaison, and command and control, and communications relay.

The Gazelle flown by the British Army Air Corps has recently been enhanced with a Direct Voice Input (DVI) system developed by QinetiQ. It allows for voice control of avionics equipment using standard aircrew helmet microphones and intercom. Being speaker independent, the system does not need to be trained to recognize a specific user. This means high command recognition rates may be achieved whether or not the user has operated the system before. It gives aircrew the ability to control aircraft systems using voice commands and access information without removing their hands from the flight controls or their eyes from the outside world.

Gazelles were also manufactured in Egypt by ABHCO and in Yugoslavia by SOKO.

Operational history

France

The French army deployed the Gazelle on many occasions, especially during interventions in Africa and peacekeeping operations. This includes Chad (1980s),

the former Yugoslavia (1990s), Djibouti (1991-1992), Somalia (1993) and Cote d'Ivoire (2002-Present). During Operation Desert Storm, HOT-carrying Gazelles were used against Iraqi armour.

Iraq

Iraq received an important number of Gazelles and HOT missiles in the '70s and '80s. They were used intensively in the Iran–Iraq War. During the Gulf War they saw little use, because of Allied air supremacy.

Syria

Syrian Gazelles were used during 1982 Lebanon War. Syrian Army claimed they had large success against Israeli armour (30 kills), while suffering medium losses. One was captured by Israel, tested and now is displayed in IAF museum.

Kuwait

Kuwait said its Gazelles were used during the Iraqi invasion, destroying some Iraqi trucks or APCs. It seems several were captured and used by Iraqi Army.

United Kingdom

The Gazelle was used in combat in the Falkland Islands, Kuwait, Iraq and Kosovo and with 8 Flight Army Air Corps in support of 22 Special Air Service Regiment. It was also used for air patrols in Northern Ireland. British Gazelles were only armed when used in the Falklands, where they were fitted with machine guns and rocket pods, but these were not used. three Gazelles were lost in action in 1982, two due to ground fire and one shotdown by a Pucara. British Gazelles performed as scouts for other attack platforms in 1991 Gulf War.



Yugoslav Air Force Soko Gazelle

Ex-Yugoslavia

SA 341/342 Gazelle GAMA (Yugoslav version) was used by Republika Srpska Air Force and Republika Srpska Krajina Militia Air Force during the Yugoslav civil wars (1991-1995), and by the Yugoslav air force during the Kosovo war.

Lebanon

Gazelles armed with machine guns, were used by the Lebanese Air Force against the Al Qaeda-inspired militants of Fatah al-Islam during the battle of Nahr el-Bared.

Morocco

24 SA342L Gazelle helicopters were bought, half of them armed with HOT missiles and the other half with 20mm guns. Some were used in Western Sahara to fight Polisario columns.

Ireland

The Irish Air Corps formerly operated two Gazelle helicopters as pilot training aircraft.

Variants

SA 340

First prototype, first flown on 7 April 1967 with a conventional Alouette type tail rotor.

SA 341

Four pre-production machines. First flown on 2 August 1968. The third was equipped to British Army requirements and assembled in France as the prototype Gazelle AH.1. This was first flown on 28 April 1970.

SA 341.1001

First French production machine. Initial test flight 6 August 1971. Featured a longer cabin, an enlarged tail unit and an uprated Turbomeca Astazou IIIA engine.

SA 341B (*Westland Gazelle AH.1*)



A Westland Gazelle AH1 of the British Army in 1983

Version built for the British Army; Featured the Astazou IIIN engine, a nightsun searchlight and Decca Doppler 80 Radar. First Westland assembled version flown on 31 January 1972, this variant entered service on 6 July 1974. A total of 158 were produced.

SA 341C (*Westland Gazelle HT.2*)

Training helicopter version built for British Fleet Air Arm; Features included the Astazou IIIN engine, a stability augmentation system and a hoist. First flown on 6 July 1972, this variant entered operational service on 10 December 1974. A total of 30 were produced.

SA 341D (*Westland Gazelle HT.3*)

Training helicopter version built for British Royal Air Force; Featuring the same engine and stability system as the 341C, this version was first delivered on 16 July 1973. A total of 14 were produced.

SA 341E (*Westland Gazelle HCC.4*)

Communications helicopter version built for British Royal Air Force; Only 1 example of this variant was produced.

SA 341F

Version built for the French Army; Featuring the Astazou IIIC engine, 166 of these were produced. Some of these were fitted with an M621 20-mm cannon.



Aerospatiale SA 341G Gazelle

SA 341G

Civil variant, powered by an Astazou IIIA engine. Officially certificated on 7 June 1972; subsequently became first helicopter to obtain single-pilot IFR Cat 1 approval in the US. Also developed into "Stretched Gazelle" with the cabin modified to allow an additional 8 inches (20cm) legroom for the rear passengers.

SA 341H

Military export variant, powered by an Astazou IIIB engine. Built under licence agreement signed on 1 October 1971 by SOKO in Yugoslavia.

SOKO HO-42

Yugoslav-built version of SA 341H.

SOKO HI-42 Hera

Yugoslav-built scout version of SA 341H.



Control panel of a Gazelle SA 342M of the French Army's Light Aviation (ALAT)

SOKO HN-42M Gama

Yugoslav-built attack version of SA 341H.

SOKO HN-45M Gama 2

Yugoslav-built attack version of SA 342L.

SOKO HS-42

Yugoslav-built medic version of SA 341H.

SA 342J

Civil version of SA 342L. This was fitted with the more powerful 649kW (870shp) Astazou XIV engine and an improved Fenestron tail rotor. With an increased take-off weight, this variant was approved on 24 April 1976 and entered service in 1977.

SA 342K

Military export version for "hot and dry areas". Fitted with the more powerful 649-kW (870-shp) Astazou XIV engine and shrouds over the air intakes. First flown on 11 May 1973; initially sold to Kuwait.

SA 342L

Military companion of the SA 342J. fitted with the Astazou XIV engine. Adaptable for many armaments and equipment, including six Euromissile HOT anti-tank missiles.

SA 342M

French Army anti-tank version fitted with the Astazou XIV engine. Armed with four Euromissile HOT missiles and a SFIM APX M397 stabilised sight.

SA 342M1

Standard SA 342M retrofitted with three Ecureuil main blades to improve performance.

Operators



Cypriot National Guard Aérospatiale Gazelle armed with HOT missiles



Bosnian Soko Gazelle



French Army Gazelle SA 342L1 at RIAT 2010



Serbian Soko Gazelle

Military operators

 Angola

- People's Air and Air Defence Force of Angola operates about 7 aircraft.

 Bosnia and Herzegovina

- Air Force and Anti-Aircraft Defense operates 4 aircraft

 Burundi

- Burundi Army Aviation operates 2 aircraft.

 Cameroon

- Cameroon Air Force operates 3 aircraft. 4 were ordered but 1 crashed

 People's Republic of China

 Cyprus

- Cypriot National Guard Air component operates 4 aircraft.

 Ecuador

- Ecuadorian Army operates about 20 aircraft.

 Egypt

- Egyptian Air Force operates about 84 aircraft.

 France

- French Army

 Gabon

- Gabon Air Force operates 5 aircraft.

 Guinea

- Guinea Air Force operates 1 aircraft.

 Iraq

- Iraqi Air Force operates 6 aircraft.

 Jordan

 Kenya

- Kenya Air Force, 1 in service in 2009

 Kuwait

- Kuwait Air Force operates 13 aircraft.

 Lebanon

- Lebanese Air Force operates 8 helicopters equipped with HOT missiles, 68 mm rocket pods, and heavy machine guns. Lebanon signed a contract with Eurotech in January 2010 to revamp and upgrade 13 Gazelles of the original and ex-UAE deliveries.

 Montenegro

- Air Defense operates 11 aircraft

 Morocco

- Royal Moroccan Air Force operates 24 aircraft.

 Qatar

- Qatar Air Force

 Rwanda

 Senegal

 Serbia

- Serbian Air Force operates 61 aircraft
 - 252. Mixed-Aviation Squadron
 - 138. Mixed-Transport-Aviation Squadron
 - 714. Anti-Armour Helicopter Squadron
 - 119. Combined-Arms Helicopter Squadron

 Syria

- Syrian Air Force operates 38 aircraft.

 Trinidad and Tobago

- Trinidad and Tobago Defence Force

 Tunisia

- Tunisian Air Force

 United Arab Emirates

- United Arab Emirates Air Force operates 1 aircraft.

 United Kingdom

- Army Air Corps - Current Units;
 - 2 Regiment AAC (Trg), *671 Sqn*
 - 5 Regiment AAC (NI), *665 Sqn*
 - Canada, *29 (BATUS) Flight*
 - Germany, *12 Flight*

Law Enforcement operators

 Bosnia and Herzegovina

-  **Republika Srpska**
- Republika Srpska Police operates 4 aircraft

Montenegro

- Montenegro Police operates 3 aircraft

Serbia

- Serbian Police Helicopter unit operates 13 aircraft

Former military operators

Ireland

- Irish Air Corps - Two aircraft operated between 1979–2005

Republika Srpska

- Republika Srpska Air Force operated 20 aircraft

United Kingdom

- Royal Air Force - 32
- Royal Marines
- Royal Navy - Fleet Air Arm

Yugoslavia

- FR Yugoslav Air Force
 - 890. Mixed-Helicopter Squadron *Pegazi*
 - 897. Mixed-Helicopter Squadron *Stršljeni*
 - 712. Anti-Armour Helicopter Squadron *Škorpioni*
 - 714. Anti-Armour Helicopter Squadron *Senke*

Yugoslavia

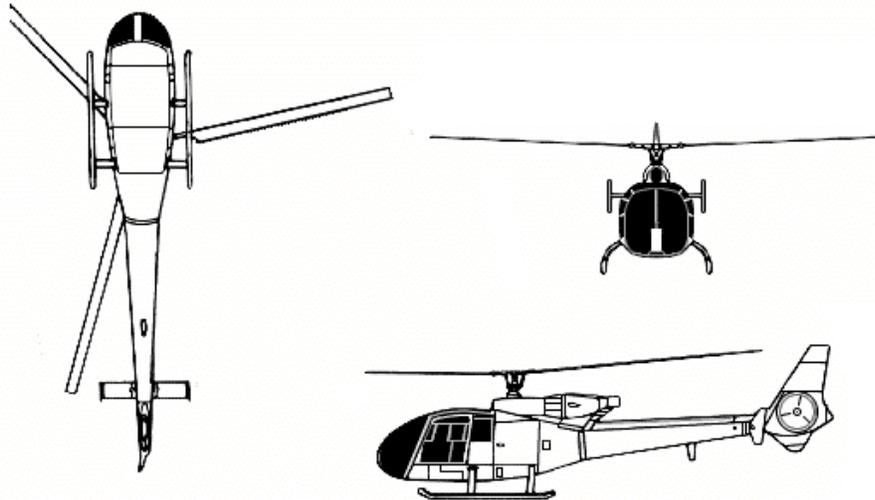
- SFR Yugoslav Air Force operated about 207 helicopters, passed to successor states
 - 890. Transport Helicopter Squadron
 - 782. Helicopter Squadron
 - 782. Helicopter Squadron
 - 783. Helicopter Squadron
 - 712. Anti-Armour Helicopter Squadron
 - 714. Anti-Armour Helicopter Squadron
 - 333. Aviation Squadron
 - 711. Anti-Armour Helicopter Squadron
 - 713. Anti-Armour Helicopter Squadron
 - EIV of 1st Army region
 - EIV of 2nd Army region

- EIV of 3rd Army region
- EIV of Navy region

 Slovenia

- Slovenian Air Force and Air Defence operated 1 aircraft from 1991 to 1996

Specifications (SA 341)



General characteristics

- **Crew:** 2
- **Capacity:** 3 Passengers
- **Length:** 11.97 m (39 ft 0 in)
- **Main rotor diameter:** 10.5 m (34 ft 6 in)
- **Height:** 3.15 m (10 ft 3 in)
- **Main rotor area:** 86.5 m² (931 ft²)
- **Empty weight:** 908 kg (2,002 lb)
- **Gross weight:** 1,800 kg (3,970 lb)
- **Powerplant:** 1 × Turbomeca Astazou IIIA turboshaft, 440 kW (590 hp)

Performance

- **Maximum speed:** 310 km/h (193 mph)
- **Cruising speed:** 264 km/h (164 mph)
- **Range:** 670 km (416 miles)
- **Service ceiling:** 5,000 m (16,405 ft)
- **Rate of climb:** 9 m/s (1,770 ft/min)

Chapter- 6

Heli-Sport CH-7

CH-7



CH-7 Kompres Charlie

Role	Ultralight kitbuilt helicopter
National origin	Italy
Manufacturer	CH-7 Heli-Sport, Turin
Designed by	Original CH-6 airframe by Augusto Cicaré, developed by Josi and Claudio Barbero; new cockpit by Marcello Gandini
Number built	c.335 by May 2009
Unit cost	(2009) €81,033 for Kompres without engine
Developed from	Cicare Helicopters CH-6

The **CH-7 Helicopters Heli-Sport CH-7** series of ultralight, kit built, helicopters is based on a single-seat Argentinian design from the late 1980s. Later developed into a tandem two seater, it continues in production and has sold in large numbers.

Design and development

In 1989 EliSport, who became Heli-Sport in 1997, bought the rights to the Cicare CH-6, a small single seat open cockpit helicopter designed in Argentina by Augusto Cicaré. It was developed by Josi and Claudio Barbero and, with the help of the sports car designer, Marcello Gandini who produced a new, enclosed, cabin, marketed from 1992 as the **CH-7 Angel**. Its commercial success led to a tandem two seat version with a stretched cabin and bigger engine named the **CH-7 Kompess** and, in 2005, a further refinement designated the **CH-7 Kompess Charlie**.

The piston engined CH-7 ultralight series use the traditional "penny-farthing" layout with two bladed main and tail rotors. The main rotor is formed from composites and is a teetering, semi-rigid design with 6° of twist. The tail rotor is aluminium. The pod and boom fuselage has a glass fibre cabin built on a steel tube frame, with a long transparent forward opening canopy. The steel frame also carries the engine, semi-exposed behind the accommodation and connected to the main rotor shaft by a belt drive. A slender aluminium boom, strengthened by a pair of long struts to the lower fuselage frame, carries both the tail rotor and swept fins. The upper fin is topped with a short horizontal tailplane, with small endplate fins, and the lower one ends with a tailskid. The CH-7 uses a simple aluminium skid undercarriage, which may be fitted with small wheels for ground handling or multi-tube inflatable floats for flying off water. In this last form the CH-7 is called the **Mariner**. The Kompess Charlie has faired, wide chord carbon fibre skid legs.

The Kompess and Kompess Charlie are sold in kit form for home assembly, the manufacturers quoting a 200 hrs building time. A fast build kit, with more components pre-assembled, is claimed to need 85 hrs.

The Kompess series may be fitted with a hook for lifting loads of up to 100 kg (220 lb), or fitted with spray bars for agricultural work.

Operational history

120 Angels were built between 1992 and 1997, followed by 215 Kompess and Kompess Charlies up to May 2009. By mid 2009 the Kompess variants had logged over 30,000 flying hours with owners in 15 countries. There are dealerships in the Czech republic, France, Italy and Poland.

In 2007 the CH-7 won the Italian Helicopter Championships. It gained 3rd place in the 2009 World Air Games.

Variants

CH-7 Angel

CH-6 with new, enclosed cockpit, powered by either 48 kW (64 hp) Rotax 582UL UL or 60 kW (80 hp) Rotax 912 UL. First marketed in 1992, but kits no longer (2010) available.

CH-7 Kompress

Tandem two seat version, with elongated cockpit and 114 hp (85 kW) Rotax 914 engine. Still available, upgradable to Kompress Charlie standard.

CH-7 Kompress Charlie

2005 development of Kompress with greater fuel capacity, hinged carbon fibre engine cowlings and carbon fibre, aerofoil section undercarriage legs. Vibration reduced and speed and high altitude performance improved.

CH-7 Mariner

Inflatable float equipped version, 15 kg (33 lb) heavier.



CH-7 Mariner at the Radom Air Show, 2007

Specifications (Kompress Charlie, European specification)

General characteristics

- **Crew:** 2
- **Length:** 7.05 m (23 ft 2 in) overall, rotors turning; fuselage length 5.31 m (17 ft 5 in)
- **Height:** 2.35 m (7 ft 9 in)
- **Empty weight:** 275 kg (606 lb)
- **Max takeoff weight:** 450 kg (992 lb)

- **Fuel capacity:** 60 L (15.8 US gal, 13.2 Imp gal) usable standard, further 19 L (5.0 US gal, 4.2 Imp gal) in optional auxiliary tank.
- **Powerplant:** 1 × Rotax 914, 84.6 kW (113.5 hp)
- **Main rotor diameter:** 6.20 m (20 ft 4 in)

Performance

- **Cruising speed:** 160 km/h (99 mph; 86 kn)
- **Never exceed speed:** 192 km/h (119 mph; 104 kn)
- **Range:** 480 km (298 mi; 259 nmi) with standard fuel load
- **Endurance:** 3 hr
- **Service ceiling:** 5,000 m (16,404 ft) service; hover ceiling out of ground effect is 2,500 m (8,200 ft)

Chapter- 7

Bölkow Bo 46

Bo 46



Bo 46, first prototype

Role	Experimental high-speed helicopter
Manufacturer	Bölkow
First flight	30 January 1964
Number built	3

The **Bölkow Bo 46** was an experimental helicopter built to test the **Derschmidt rotor system** that aimed to allow much higher speeds than traditional helicopter designs. Wind tunnel testing showed promise, but the Bo 46 demonstrated a number of problems and added complexity that led to the concept being abandoned. The Bo 46 was one of a number of new designs exploring high-speed helicopter flight that were built in the early 1960s.

Background

Helicopter rotors operate in a much more challenging environment than a normal aircraft propeller. To start with, helicopters normally use the main rotor both for lift and manoeuvrability, whereas fixed-wing aircraft normally use separate surfaces for these tasks. Pitch and yaw are operated by changing the lift on different sides of the rotor, using a system of bell cranks to adjust the blades to different angles of attack as they rotate. To roll to the left, the blades are adjusted so there is slightly more angle of attack on the right and slightly less on the left, resulting in a net upward lift on the right side that rolls the aircraft.

In forward flight, the rotor system is subject to various forms of differential loading. Imagine a rotor system where the tips of the blades rotate at 300 km/h relative to still air. When that helicopter is hovering, the blades see the same 300 km/h relative wind throughout their rotation. However, when the helicopter starts to move forward its speed is added to the speed of the blades as they advance towards the front of the aircraft, and subtracted as they retreat. For instance, if the helicopter is flying forward at 100 km/h, the advancing blades see $300 + 100 \text{ km/h} = 400 \text{ km/h}$, and for the retreating ones its $300 - 100 \text{ km/h} = 200 \text{ km/h}$.

In this example, the relative airspeed changes by a factor of two during every rotation. Lift is a function of the angle of the airfoil to the relative airflow combined with the speed of the air. To counteract this change in lift, which would normally roll the aircraft, the rotor system has to dynamically adjust the angle of the airfoils to ensure they generate a steady amount of lift throughout their motion. This adjustment is in addition to any that is being applied deliberately to manoeuvre. Since every control system has some mechanical limit, as the aircraft speeds up it loses manoeuvrability.

Drag is a function of the square of airspeed, so the same changes in speed cause the drag to vary by a factor of four. To reduce the net force as much as possible, helicopter blades are designed to be as thin as possible, reducing their drag, although this makes them inefficient for lift. In the 1950s, helicopter blades were made in much the same fashion as fixed-wing aircraft wings; a spar ran the length of the rotor blade and provided most of the structural strength, while a series of stringers give it the proper aerodynamic shape. This method of construction, given the materials of the era, placed enormous stresses on the spar.

To lessen the loads, especially the rapid changes, the rotor hubs included a system of bearings that allow them to move forward or back in response to drag, and up and down in a flapping motion in response to changing speed. These were in addition to the system used to change the angle of attack to provide control; rotor hubs tended to be very complex.

Performance limits

There is a limit to the rotor's ability to adjust to these changing loads, and this places a limit on the maximum speed of the helicopter.

All wings have a critical angle of attack where increases to the angle do not result in additional lift. This point is better known as the stall point. If a given helicopter airfoil design has a stall point at 100 km/h, which is not unusual, then when it is mounted to the hypothetical design above, the helicopter cannot travel any faster than 200 km/h; at that speed the retreating blades will be moving at their stall speed.

One solution to this problem is to spin the rotor faster; this maximizes the speed difference between the rotor tips and the fuselage, thereby increasing the aircraft speed where the rearward moving blades are nearing the stall point. However, this process also has its limits. As any airfoil approaches the speed of sound it encounters a problem known as wave drag that significantly increases drag, dominating efforts to add more power and sharply reducing efficiency. If the speed of the hypothetical design were doubled to 600 km/h, the advancing blades would start reaching these speeds when the aircraft reached about 200 km/h forward speed.

So the maximum speed of a helicopter is constrained by two factors. Increasing the rotational speed of the rotor decreases the forward speed where wave drag becomes a problem, but decreasing the speed of the rotor decreases the speed where the stall point becomes a problem. In practice, there are additional dynamic forces and limits to motion that limit helicopter designs to speeds far below the limits imposed above.

Derschmidt's solution

The basic problem inherent in rotor design is the difference in airspeed for the advancing and retreating blades. Among the many effects this causes is one of interest; the blades rotate forward and backward around the hub as drag increases and decreases. Consider a blade as it reaches the rear of the aircraft and starts to rotate forward; during this time the relative airspeed starts increasing rapidly, and the blade is pushed further and further back by the increasing drag. This force is absorbed in a drag bearing. During the brief period while it rotates around this bearing, the overall speed of the blade is decreased, slightly offsetting the speed due to forward motion.

Derschmidt's rotor design deliberately exaggerates this rotation to offset the increase and decrease in speed throughout the blade's rotation. At the same point of rotation as the traditional blade above, a Derschmidt rotor has advanced the blade considerably to an angle of about 40 degrees compared to its rest position straight out from the hub. As the blade continues advancing, a linkage swings the blade from 40 degrees forward to 40 degrees rearward, slowing the tip by about 1/2 the rotational speed. This process is reversed as the blade reaches its forward-most position, increasing the speed of the blade as it retreats.

The resulting motion helps smooth out the relative airspeed seen by the blade. Since the effects of the forward motion of the helicopter are reduced, or even eliminated at lower speeds, the rotor can be spun at a high speed without fear of reaching the wave drag regime. At the same time, the speed of the retreating blade never approaches the stall point. Likewise, changes in drag are even more reduced, to the point of being negligible. This allows the Derschmidt rotor to be a rigid design, eliminating the complex series of bearings, flexible fittings and linkages used in conventional rotors.

Since the motion in the Derschmidt rotor follows the natural change in drag through the rotation, the force applied to the blades to move them into position is quite small. Of the several designs he presented in his early patents, most used a very small linkage from a bell crank on the inner side of the blade attached to a small pushrod for operation. These rods were attached to a disk set eccentrically to the centre of rotation, which drove the blades into their proper locations.

Last in the series of designs was a different approach that used a single counterweight for each blade, geared so its motion was mechanically amplified. The weight was selected to create a harmonic pendulum at the rotor's design speed. There was no mechanical attachment between the blades, and the entire assembly sat outside the hub, leaving ample room for maintenance.

Bo 46

Bölkow had been interested in high-speed rotor flight for some time, and had drawn up several experimental concepts based on tip jet systems. Later they took on the job of developing a glass-fibre composite blade that was much stronger than the existing metal designs. When Derschmidt received his first patent in 1955, Bölkow took up the concept and started work on the **Bölkow Bo 46** as an experimental testbed, paid for by a Ministry of Defence contract.

The basic Bo 46 design was finalized in January 1959. The five-bladed rotor system was initially tested in a wind tunnel and turned in impressive results. These suggested that the Bo 46 would be able to reach speeds up to 500 km/h, whereas even advanced designs of the era were limited to speeds around 250 km/h. Construction of three highly-streamlined fuselages started at Siebel. There were powered by an 800 hp Turboméca Turmo turboshaft driving a five-bladed Derschmidt rotor. The design originally featured a louvred fenestration for the anti-torque rotor that could be closed in high speed flight, but this was removed from the prototypes and the six-bladed rotor was conventionally mounted on the left side of the tail. The maximum speed was not limited by rotor considerations, but the maximum power of the engine. Adding separate engines for additional forward thrust was expected to allow speeds as high as 700 km/h.

During the early 1960s the company also outlined several production designs, most using twin rotors, the largest of these was the Bo 310. This was powered by two T55 or T64 engines, each of which drove both a Derschmidt rotor and a forward-facing propeller for additional forward thrust. Several versions of the Bo 310 were modelled, mostly

passenger transports, but also attack helicopter versions. The Bo 310 would have a cruise speed of 500 km/h.

Initial test flights with the rotors locked started in the autumn of 1963. In testing a series of unexpected new types of dynamic loads were encountered, which led to dangerous oscillations in the rotor. These did not appear to be inherent to the design itself, but they could only be cured through additional complexity in the rotor. During the same period, rotor design was moving to composite blades that were much stronger than the older spar-and-stringer designs, which eliminated the need for the complex bearing system that relieved loads. Although the Derschmidt rotor still improved performance, it appeared the added complexity was not worthwhile.

Interest in the system waned, but research flights continued. The Bo 46 was eventually equipped with two Turboméca Marboré engines, allowing a speed of 400 km/h. The fibreglass bladed rotor proved to be workable however, and would go on to see wide service in the Bölkow Bo 105.

Aircraft on display

A preserved example of the Bo 46 is on public display at the Hubschrauber Museum, Bückeburg.

Specifications (Bo 46)

General characteristics

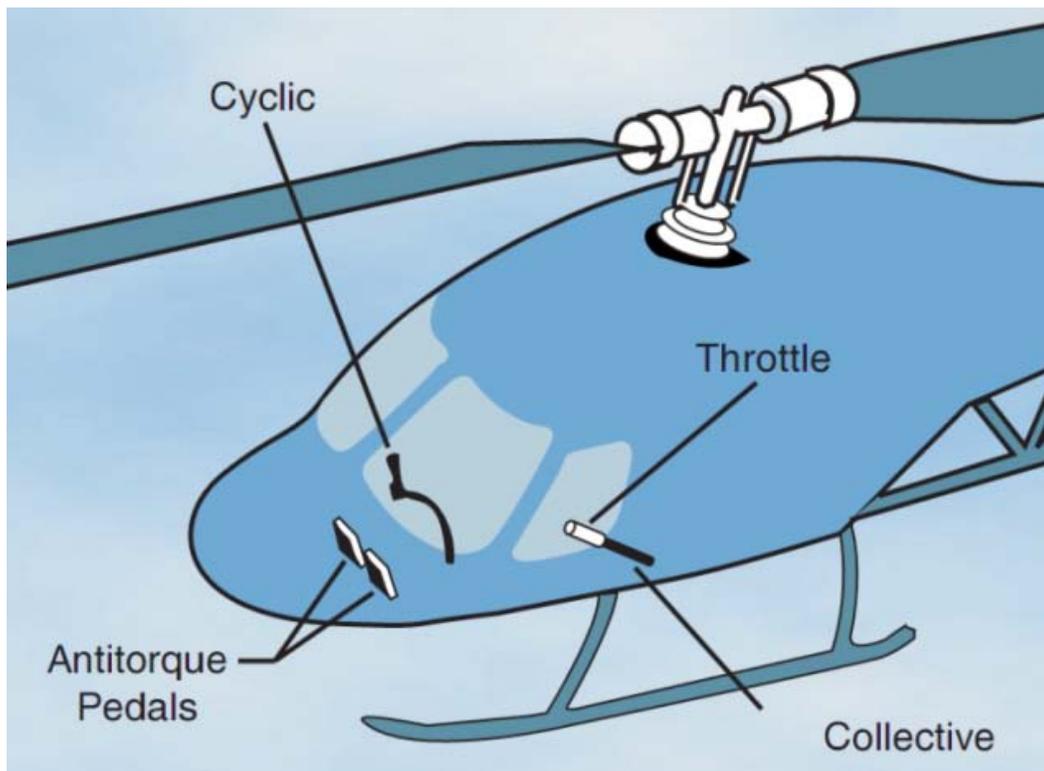
- **Crew:** one pilot
- **Capacity:** 1 passenger/observer
- **Main rotor diameter:** 10.00 m (32 ft 10 in)
- **Main rotor area:** 78.5 m² (845 ft²)
- **Gross weight:** 2,000 kg (4,400 lb)
- **Powerplant:** 1 × Turboméca Turmo IIIB, 597 kW (800 hp)

Performance

- **Maximum speed:** 320 km/h (200 mph)

Chapter- 8

Helicopter Flight Controls



Location of flight controls in a helicopter

A helicopter pilot manipulates the **helicopter flight controls** in order to achieve controlled aerodynamic flight. The changes made to the flight controls are transmitted mechanically to the rotor, producing aerodynamic effects on the helicopter's rotor blades which allow the helicopter to be controlled. For tilting forward and back (pitch), or tilting sideways (roll), the angle of attack of the main rotor blades is altered *cyclically* during rotation, creating differing amounts of lift at different points in the cycle. For increasing or decreasing overall lift, the angle of attack for all blades is *collectively* altered by equal amounts at the same time resulting in ascents, descents, acceleration and deceleration.

A typical helicopter has three separate flight control inputs. These are the cyclic stick, the collective lever, and the anti-torque pedals. Depending on the complexity of the

helicopter, the cyclic and collective may be linked together by a *mixing unit*, a mechanical or hydraulic device that combines the inputs from both and then sends along the "mixed" input to the control surfaces to achieve the desired result. The manual throttle may also be considered a flight control because it is needed to maintain rotor speed on smaller helicopters without governors.

Controls

Cyclic

The cyclic control is usually located between the pilot's legs and is commonly called the *cyclic stick* or just *cyclic*. On most helicopters, the cyclic is similar in appearance to a joystick in a conventional aircraft. By contrast, the Robinson R22 and Robinson R44 have a unique teetering bar cyclic control system and a few early helicopters have had a cyclic control that descended into the cockpit from overhead, one example being the HC-2 "Heli Baby", HC-102. The control is called the cyclic because it changes the pitch of the rotor blades cyclically. That is, the pitch or *feathering angle* of the rotor blades changes depending upon their position as they rotate around the hub so that all blades will change their angle the same amount at the same point in the cycle. The change in cyclic pitch has the effect of changing the angle of attack and thus the lift generated by a single blade as it moves around the rotor *disk*. This in turn causes the blades to fly up or down in sequence, depending on the changes in lift affecting each individual blade.

The result is to tilt the rotor disk in a particular direction, resulting in the helicopter moving in that direction. If the pilot pushes the cyclic forward, the rotor disk tilts forward, and the rotor produces a thrust vector in the forward direction. If the pilot pushes the cyclic to the right, the rotor disk tilts to the right and produces thrust in that direction, causing the helicopter to move sideways in a hover or to roll into a right turn during forward flight, much as in a conventional aircraft.

On any rotor system there is a delay between the point in rotation where a change in pitch is introduced by the flight controls and the point where the desired change is manifest in the rotor blade's flight. While often discussed as gyroscopic precession for ease of teaching, this phase lag varies with the geometry of the rotor system and is the angular difference between the point of application of a cyclic pitch change and the point where the effect of that pitch change reaches maximum amplitude. This lag is an example of a dynamic system in resonance but is never more than ninety degrees.

Collective

The collective pitch control, or *collective lever*, is normally located on the left side of the pilot's seat with an adjustable friction control to prevent inadvertent movement. The collective changes the pitch angle of all the main rotor blades collectively (*i.e.*, all at the same time) and independent of their position. Therefore, if a collective input is made, all the blades change equally, and the result is the helicopter increases or decreases its total lift derived from the rotor. In level flight this would cause a climb or descent, while with

the helicopter pitched forward an increase in total lift would produce an acceleration together with a given amount of ascent.

Anti-torque pedals

The anti-torque pedals are located in the same position as the rudder pedals in an airplane, and serve a similar purpose, namely to control the direction in which the nose of the aircraft is pointed. Application of the pedal in a given direction changes the pitch of the tail rotor blades, increasing or reducing the thrust produced by the tail rotor and causing the nose to yaw in the direction of the applied pedal. The pedals mechanically change the pitch of the tail rotor altering the amount of thrust produced.

Throttle

Helicopter rotors are designed to operate at a specific rotational speed. The *throttle* controls the power produced by the engine, which is connected to the rotor by a transmission. The purpose of the throttle is to maintain enough engine power to keep the rotor speed within allowable limits in order to keep the rotor producing enough lift for flight. In single-engine helicopters, the throttle control is a motorcycle-style twist grip mounted on the collective control, while dual-engine helicopters have power levers.

In many piston engine-powered helicopters, the pilot manipulates the throttle to maintain rotor speed. Turbine engine helicopters, and some piston helicopters, use governors or other electro-mechanical control systems to maintain rotor speed and relieve the pilot of routine responsibility for that task. (There is normally also a manual reversion available in the event of a governor failure.)

Helicopter controls and effects

Name	Directly controls	Primary effect	Secondary effect	Used in forward flight	Used in hover flight
Cyclic (lateral)	Varies main rotor blade pitch with left and right movement	Tilts main rotor disk left and right through the swashplate	Induces roll in direction moved	To turn the aircraft	To move sideways
Cyclic	Varies	Tilts main rotor	Induces pitch	Control	To move

(longitudinal)	main rotor blade pitch with fore and aft movement	disk forward and back via the swashplate	nose down or up	attitude	forwards/backwards
Collective	Collective angle of attack for the rotor main blades via the swashplate	Increase/decrease pitch angle of all main rotor blades equally, causing the aircraft to ascend/descend	Increase/decrease torque. Note: in some helicopters the throttle control(s) is a part of the collective stick. Rotor speed is kept basically constant throughout the flight.	To adjust power through rotor blade pitch setting	To adjust skid height/vertical speed
Anti-torque pedals	Collective pitch supplied to tail rotor blades	Yaw rate	Increase/decrease torque and engine speed (less than collective)	Adjust sideslip angle	Control yaw rate/heading

Flight conditions

There are two basic flight conditions for a helicopter; hover and forward flight.

Hover

Hovering is the most challenging part of flying a helicopter. This is because a helicopter generates its own gusty air while in a hover, which acts against the fuselage and flight control surfaces. The end result is constant control inputs and corrections by the pilot to keep the helicopter where it is required to be. Despite the complexity of the task, the control inputs in a hover are simple. The cyclic is used to eliminate drift in the horizontal plane, that is to control forward and back, right and left. The collective is used to maintain altitude. The pedals are used to control nose direction or heading. It is the interaction of these controls that makes hovering difficult, since an adjustment in any one control requires an adjustment of the other two, creating a cycle of constant correction.

Forward flight

In forward flight a helicopter's flight controls behave more like those in a fixed-wing aircraft. Displacing the cyclic forward will cause the nose to pitch down, with a resultant increase in airspeed and loss of altitude. Aft cyclic will cause the nose to pitch up, slowing the helicopter and causing it to climb. Increasing collective (power) while maintaining a constant airspeed will induce a climb while decreasing collective will cause a descent. Coordinating these two inputs, down collective plus aft cyclic or up collective plus forward cyclic, will result in airspeed changes while maintaining a constant altitude. The pedals serve the same function in both a helicopter and an airplane, to maintain balanced flight. This is done by applying a pedal input in whichever direction is necessary to center the ball in the turn and bank indicator.

Differential pitch control

For helicopters with contra-rotating rotors, helicopter control requires interaction between the two rotors. A helicopter with tandem rotors uses differential collective pitch to change the attitude of the nose of the aircraft. To pitch nose down and accelerate forward, the collective pitch on the front rotor is decreased and the collective pitch on the rear rotor is increased proportionally. Conversely, the synchropter and transverse-mounted rotor helicopters use differential collective pitch to affect the roll of the aircraft. All of these configurations use differential cyclic pitch to control movement about the yaw axis, tilting the rotors in opposite directions to cause the aircraft to spin in the direction of the tilted rotors.

Chapter- 9

Helicopter Equipments

Helicopter Aircrew Breathing Device

The **Helicopter Aircrew Breathing Device** or **HABD** is a piece of military survival gear which was adopted in order to increase the chances of survival for embarked troops and aircrew trapped in an aircraft which has ditched (crashed into a body of water.) Similar in function to SCUBA gear, it consists of a small cylinder pressurized with atmospheric air and first stage regulator worn in a pouch on the user's flotation vest; a pressure gauge; an air hose and a special second-stage regulator (the part that delivers air via the user's mouth). The regulator is on-demand (it only delivers air when the user breathes in) and is designed to be highly rugged in order to survive impacts associated with emergency ditchings.

Since a full-size SCUBA cylinder would be prohibitively bulky, especially for troops already laden with full combat gear, the HABD must be small and thus limited in capacity. It provides roughly two minutes of air at the surface. This decreases rapidly with depth and with the heightened breathing rate that accompanies stress. Still, even a few breaths in such a situation can mean the difference between life and death.

Helicopter ditchings usually come with little warning, often while the pilot is attempting a ship landing or other low-altitude maneuver. Because they are top-heavy, ditched helicopters invariably flip upside-down upon hitting the water. The crew and embarked troops will be bombarded with violent jerking motions and several tons of incoming water, which causes unsecured gear to fly uncontrolled throughout the cabin and can knock troops unconscious. Jet fuel and hydraulic fluid often seep into the cabin and can cause blindness to open eyes and lung damage if inhaled. Troops unfortunate enough to find themselves in a ditched helicopter will be upside-down, disoriented, often in the dark and in a rapidly-sinking bird. Immersion in cold water evokes a "gasp" response in humans, which limits their breath-holding ability to as little as 15 seconds. Panic is fatal. The HABD, properly used, provides troops with an invaluable tool to help ward off panic and buys them precious extra time to escape. HABD are also known as HEEDS III and SEA

Helicopter bucket



A-Flex collapsible Monsoon Bucket



This photo, taken from a USN UH-3 Sea King, shows a Bambi bucket used to combat brush fires in California.

A **helicopter bucket** is a specialised bucket suspended on a cable carried by a helicopter to deliver water for aerial firefighting. Each bucket has a release valve on the bottom which is controlled by the helicopter crew. When the helicopter is in position, the crew releases the water to extinguish or suppress the fire below. Each release of the water is referred to as a drop. The design of the buckets allows the helicopter to hover over a water source – such as a lake, river, pond, or tank – and lower the bucket into the water to refill it. This allows the helicopter crew to operate the bucket in remote locations without the need to return to a permanent operating base, reducing the time between successive drops.

Buckets can be collapsible or rigid and vary in capacity from 72 to 2,600 gallons (275 to 9,840 liters). The size of each bucket is determined by the lifting capacity of the helicopter required to utilise each version. Some buckets can include fire retardant foam or the ability to pump water from the bucket into an internal tank. Smaller collapsible buckets can use water sources as shallow as 1 foot (30.5 cm). Worldwide, the term *monsoon bucket* is widely used and accepted as a generic term. In the United States, this type of bucket is officially referred to as a *helibucket*. The trademarked *Bambi Bucket* is also commonly used informally by firefighting crews to describe buckets developed by other manufacturers.

Variants

A-Flex Firefighting Monsoon Bucket

Collapsible bucket produced by A-Flex Technology.

Bambi Bucket

Collapsible bucket developed by Canadian Don Arney and produced by SEI Industries since 1983.

CLOUDBURST Fire Bucket

Collapsible bucket produced by IMSNZ Ltd.

FAST Bucket

Variable Drop, fire fighting bucket that allows the pilot to select drop patterns for bush fires to canopy fires. manufactured by Absolute Fire Solutions.

HELiFIRE Monsoon Bucket

Collapsible bucket produced by Fire & Rescue New Zealand, a non-governmental rural fire service.

Water Hog Bucket

Lightweight, collapsible, free-standing bucket developed and produced by Aerial Fire Control Pty Ltd since 2001.

Helicopter helmet



SPH-5 helicopter helmet

A **Helicopter helmet** is headgear worn by a helicopter pilot or crew. The basic use of the helmet is to protect the head and provide a portable communications system for the user. There are three companies that make helicopter helmets and they are Gentex, MSA and Interactive safety. All three brands are in current production, and sold as the Gentex SPH-5, MSA Galle or Alpha eagle. The major differences in these helmets are Weight and Features.

Most helmets are made of Kevlar and provide features like:

- sun visor
- microphone

Helicopter emergency egress device

Helicopter Emergency Egress Device (HEED) is a small scuba tank worn by pilots and crewmen of helicopters in the event that they are trapped for a short period of time underwater following a ditching or crash over water. HEED Bottles come in different sizes and are generally found in the 1.7 to 3.0-cubic-foot (85 L) range. HEED systems also come with hose regulators and are known as Helicopter Aircrew Breathing Device (HABD).

Helicopter rescue basket



An aerial rescue basket in water survival training

A **helicopter rescue basket** is a basket suspended below a helicopter in order to rescue people from a fire or other disaster site.

Uses



U.S. Coast Guard helicopter with rescue basket



Heli-Basket® in Anderson, SC



Heli-Basket® in Venezuela

There are two main types of helicopter baskets. The smaller, more common type is used by rescuers to lift a person up from ground or water into the helicopter.

The second type is a new invention. This is a basket able to fit five people or more. It allows a large group of people to be rescued from a fire or other emergency site, without needing to load them into the helicopter itself. It enables the helicopter to load a large group without landing. The helicopter hovers over the site and rests the basket on the ground or other surface. Evacuees board, then are transported to a safe area.



Basket rescue after Hurricane Katrina

This type of basket was tested by the Air National Guard in 2006, and were found to be quite functional. Guard personnel tested out a basket which could fit up to 15 people, at the Air National Guard-Air Force Reserve Command Test Center at Tucson, Ariz. The basket which was tested is known as the Heli-Basket®, is 4-and-a-half foot by 8-and-a-half feet, and hangs on a 125-foot cable below an HH-60G Pave Hawk helicopter. It was invented by John Tollenaere, of the company Precision Lift, Inc.

Chapter- 10

Hazards for Helicopter

Settling with power

In helicopter flight, it is possible for the rotors to descend into their own downwash, a cone of turbulent air previously forced downward in the generation of lift. As turbulent air doesn't have the same physical properties as still or *clean* air, the rotors produce less lift and the aircraft may descend further into the turbulent air. **Settling with power** describes such a helicopter's descent, or *settling*, even with adequate engine power to continue flight.

The more precise description of the condition is of a rotor experiencing vortex ring state. Vortex ring state, the aerodynamic condition that causes the settling, occurs when a helicopter develops excessive descent rates at low speeds and high power settings, depending also on gross weight, winds, etc.

Description

A helicopter normally encounters settling with power when attempting to hover out of ground effect above the hovering ceiling for the aircraft, hovering out of ground effect without maintaining precise altitude control, and while making downwind or steep, powered approaches when the airspeed drops to nearly zero. The signs of settling with power are a vibration in the main rotor system followed by an increasing sink rate and possibly a decrease of cyclic authority. The failure of a helicopter pilot to recognize and react to the condition can lead to high descent rates and impact with terrain, a frequently fatal event.

In forward flight, there is no upward flow (*upflow*) of air in the hub area. As forward airspeed decreases and vertical descent rates increase, an upflow begins because there are no airfoil surfaces in the mast and blade grip area. As volume of upflow increases, the induced flow (air pulled or "induced" down through the rotor system) of the inner blade sections is overcome and the blades begin to stall near the hub. As the inner blade sections stall, a second set of vortices, similar to the rotor tip vortices, form in the center of the rotor system. The inner set of vortices decreases the amount of lift being produced and causes an increase in sink rate. In an accelerated condition, the inner and outer vortices actually begin to feed each other to the point where any increase in rotor blade

pitch angle actually increases the interaction between the vortices and increases the rate of descent.

Pilot's reaction

Helicopter pilots are most commonly taught to avoid settling with power by monitoring their rates of descent at lower airspeeds. When encountering settling with power, pilots are taught to apply forward cyclic to fly out of the condition or lowering collective pitch. While transitioning to forward or lateral flight will alleviate the condition by itself, lowering the collective to reduce the power demand decreases the size of the vortices and reduces the amount of time required to be free of the condition. However, since the condition often occurs near the ground, lowering the collective may not be an option; a loss of altitude will occur proportional to the rate of descent developed before beginning the recovery. In some cases, vortex ring state is encountered and allowed to advance to the point that the pilot may lose cyclic authority due to the disrupted airflow. In these cases, the pilot's only recourse may be to enter an autorotation to break the rotor system free of its vortex ring state.

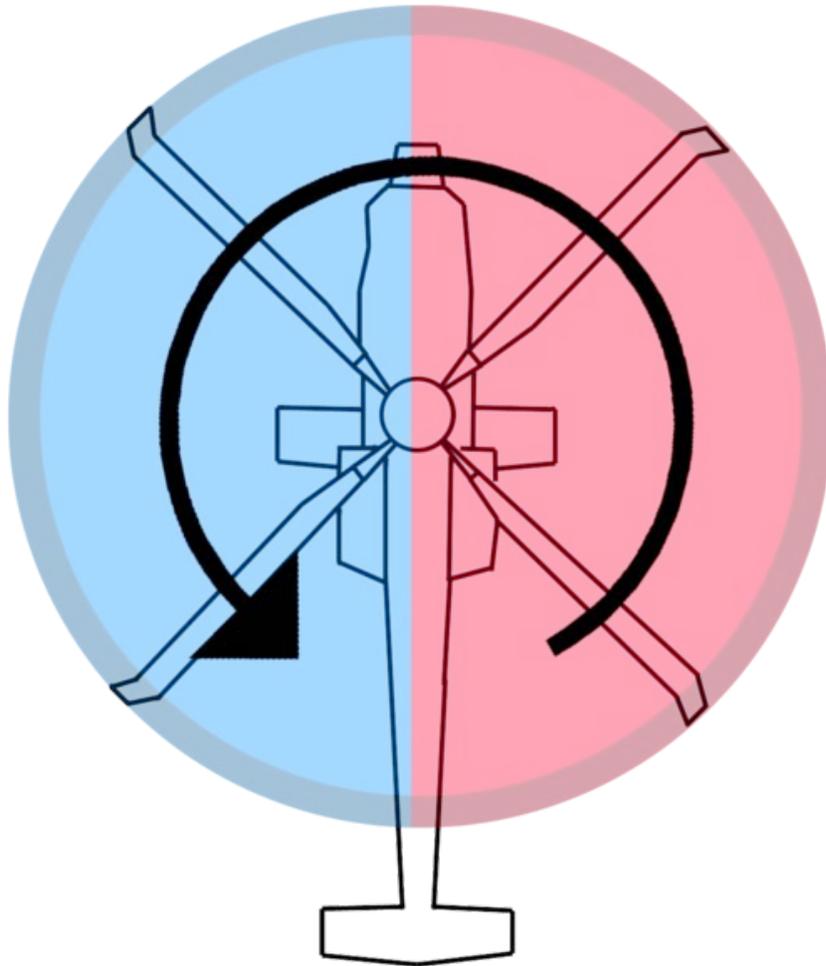
Tandem rotor helicopters

In a tandem rotor helicopter, forward cyclic will not arrest the rate of descent caused by settling with power. In such a helicopter, which utilizes differential collective pitch in order to gain airspeed, lateral cyclic inputs must be made accompanied by pedal inputs in order to slide horizontally out of the vortex ring state's disturbed air.

Retreating blade stall

Retreating blade stall is a hazardous flight condition in helicopters and other rotary wing aircraft, where the rotor blade rotating away from the direction of flight stalls. The stall is due to low relative airspeed and/or excessive angle of attack (or AOA). Retreating blade stall is the primary limiting factor of a helicopter's airspeed, and the reason even the fastest helicopters can only fly slightly faster than 200 knots.

Advancing vs. retreating blades



retreating blade side advancing blade side

A rotor blade that is moving in the same direction as the aircraft is called the *advancing blade* and the blade moving in the opposite direction is called the *retreating blade*.

Balancing lift across the rotor disc is important to a helicopter's stability. The amount of lift generated by an airfoil is proportional to its airspeed. In a zero airspeed hover the rotor blades, regardless of their position in rotation, have equal airspeeds and therefore equal lift. In forward flight the advancing blade has a higher airspeed than the retreating blade, creating unequal lift across the rotor disc.

A fuller treatment is provided in dissymmetry of lift.

Compensation

Most helicopter designs compensate for this by incorporating a certain degree of "flap" of the rotor blades through articulation of the rotor head and/or individual rotor blades,

depending on the type of rotor system. When flapping, a rotor blade will travel upward during its advance, creating a lesser Angle of Attack (AOA) and therefore lesser lift. When the blade retreats, the blade travels downward to flap down, increasing the AOA and therefore generating greater lift. Semi-rigid and Fully articulated rotors are two common designs which compensate for the effects of dissymmetry of lift through mechanical means in the rotor head. Semi-rigid rotor systems flap both blades in equal and opposite motion as the rotor head teeters on a teetering hinge. Fully-articulated rotor systems accomplish flapping motion primarily with independent mechanical movement about a flapping hinge and/or span-wise flexing of the rotor blades. In the case of the less common Rigid rotor system, the only method used for articulating flap is to allow the rotor blades to independently have a certain degree of span-wise flex and not at their attachment point to the rotor head.

The pilot may compensate the induced roll with left or right cyclic control input (as determined by the rotation of the rotor) up to a degree. However, the rapid rate of change of blade flex and angle of attack causes uncontrolled longitudinal twist and severe vibration in later stages, resulting in total loss of cyclic control if left unchecked.

Assuming no rotor damage, recovery from the condition is possible by using the procedure described below under Flight performance during a retreating blade stall.

Failure

These compensations can only do so much. Increasing angle of attack to compensate for reduced blade airspeed has the effect of maintaining lift only until the point where critical angle of attack is reached, after this point lift sharply decreases. This situation is called retreating blade stall.

All airfoils have a critical angle of attack (also called a stall angle of attack) which is the angle of attack that produces most lift. Above this angle flow over the airfoil becomes detached and lift decreases, this is commonly called a stall.

When a fixed-wing aircraft exceeds its critical angle of attack the entire aircraft loses lift and enters a condition called a stall. The usual results of a fixed-wing stall are a sharp drop in aircraft altitude and a dive. Stalls in fixed-wing aircraft are often a recoverable event.

In a retreating-blade stall, however, only the retreating half of the helicopter's rotor disc experiences a stall. The advancing blade continues to generate lift, but the retreating blade enters a stall condition, usually resulting in an uncommanded increase in pitch of the nose and a roll in the direction of the retreating side of the rotor disc. In counter-clockwise rotating rotor systems (as in most American-made types) this is the left side. In clockwise rotating systems it is a roll to the right.

Flight performance during a retreating blade stall

As the aircraft approaches the airspeed at which it will encounter retreating blade stall, the aircraft will shudder and the nose will begin to pitch up. The resultant upward pitching of the aircraft's nose will begin to correct the situation as it results in slowing the aircraft. However, if uncorrected, and if the aircraft continues to accelerate, the aircraft may roll in the direction of the retreating blade.

Recovery involves decreasing the angle of attack and allowing the retreating blade to recover from its stalled condition. This is done by lowering the collective pitch.

The stall will not happen due to speed, but a higher pitch on the retreating side. If you are at speed and immediately reduce collective you have potentially put the blade back in a non-stalled state, but you will now begin to slow down, descend and level out.

Causes of retreating blade stall

Retreating blade stall is more likely to occur when the following conditions exist either alone or in combination:

- High gross weight
- High airspeed
- Low rotor RPM
- High density altitude
- Steep or abrupt turns
- Turbulent ambient air

Retreating blade stall starts at the tip region and develops inboard (one of the exam questions in Helicopter Principles of Flights).

Ground resonance

Ground resonance, in fully articulated multi-bladed helicopters, is a hazardous condition during touchdown or at other times when the helicopter is running while sitting on the ground. A series of shocks to the landing gear can pass through to the rotor disk and cause an imbalance in the rotor system. Under extreme conditions, the imbalance causes violent oscillations that quickly build and result in catastrophic damage of the entire airframe. In some cases, complete destruction occurs, e.g. body panels, fuel tanks, and engines are all ripped from their mountings.

The imbalance is possible because multi-bladed helicopters include lag-lead hinges at the rotor hub to reduce stresses in flight. Under normal conditions, all blades are spaced at

equal angles. Shocks to the rotor mast and hub can cause an imbalance if they are sufficiently violent. Note that two-bladed helicopters are not susceptible to ground resonance because they do not require lag-lead hinges. Two-bladed rotors remain balanced through all flight conditions.

Recovery is possible in some cases. If sufficient rotor RPM exists, immediate takeoff can restore rotor balance. If rotor RPM is low, complete shutdown might be sufficient.

Low-g condition

Low-g condition is a phase of aerodynamic flight where the airframe is temporarily unloaded. The pilot—and the airframe—feel temporarily "weightless" because the aircraft is in free-fall or decelerating vertically at the top of a climb. It may also occur during an excessively rapid entry into autorotation. This can have a disastrous effect on the aircraft, particularly in the case of helicopters, some of which need the rotor to constantly be under a non-zero amount of load.

Effects

In smaller airplanes

Most smaller airplanes and all gliders have no problems with 0g conditions. In fact, it can be enjoyable to have zero gravity in the cockpit. To produce 0g, the aircraft has to follow a ballistic flight path, which is essentially an upside down parabola. This is the only method to simulate zero gravity for humans on earth.

In helicopters

In contrast, low-g conditions can be disastrous for helicopters. In such a situation their rotors may flap beyond normal limits into a condition known as mast bumping, which can cause the rotor to droop and shear the mast, and hence detach the whole system from the aircraft, falling from the sky. This is especially true for helicopters with teetering rotors, such as the two-bladed design seen on Robinson helicopters. This effect was first discovered when many accidents with Bell UH-1 and AH-1 helicopters occurred. These particular helicopters simply crashed without any obvious cause. Later, it was found that these accidents usually happened during low terrain following flight while passing a ridge and initiating a dive from the previous climb. Articulated and rigid rotor systems do not lose controlling forces up to 0g, but may encounter this depending on their flapping hinge offset from the mast. However, dangerous situations, as with a teetering rotor, may not occur.

On fixed-wing aircraft

Low-g conditions can also affect fixed-wing aircraft in some instances, mainly by disrupting the airflow over the wings, making them difficult or impossible to control via the aerodynamic surfaces.

The controllability of an airplane by the control surfaces only depends on airspeed. So, if one keeps airspeed, control is retained. Usually the controllability is even increased, because there is no need to produce lift. However, despite increased lift, g-forces will hinder aerobatic flight as velocity increases, making the compromise between speed and g-forces necessary. 0g forces are a minimal problem for fixed wing aircraft, but there are exceptions, including, but not limited to, airplanes with gravity-fed fuel systems, as well as airplanes with low airspeed. An airplane with low airspeed at 0g will stall until airspeed is recovered.

Use in space agencies

Every space agency uses a modified passenger jet (especially stronger engines) to simulate a low-g condition. The ESA uses an Airbus A300, for example. NASA has the Vomit Comet. One upside down parabola simulates 0g for about 25 s, in the following normal parabola the aircraft is loaded with 2g.

Dynamic rollover

A helicopter is susceptible to a lateral rolling tendency, called **dynamic rollover**, when lifting off the surface. For dynamic rollover to occur, some factor has to first cause the helicopter to roll or pivot around a skid, or landing gear wheel, until its critical rollover angle is reached. Then, beyond this point, main rotor thrust continues the roll and recovery is impossible. If the critical rollover angle is exceeded, the helicopter rolls on its side regardless of the cyclic control corrections made.

Dynamic rollover begins when the helicopter starts to pivot around its skid or wheel. This can occur for a variety of reasons, including the failure to remove a tiedown or skid securing device, or if the skid or wheel contacts a fixed object while hovering sideward, or if the gear is stuck in ice, soft asphalt, or mud. Dynamic rollover may also occur if the pilot does not use the proper landing or takeoff technique or while performing slope operations. Whatever the cause, if the gear or skid becomes a pivot point, dynamic rollover is possible if the pilot does not use the proper corrective technique.

Once started, dynamic rollover cannot be stopped by application of opposite cyclic control alone. For example, if the right skid contacts an object and becomes the pivot point while the helicopter starts rolling to the right. Even with full left cyclic applied, the

main rotor thrust vector and its moment follows the aircraft as it continues rolling to the right. Quickly applying down collective is the most effective way to stop dynamic rollover from developing. Dynamic rollover can occur in both skid and wheel equipped helicopters, and all types of rotor systems.

Related topics

Static rollover

Static Rollover is a rolling action when the helicopter blades are not in rotation. When the rotor blades stop, the helicopter has the same principles of any other object and will roll if the static rollover critical angle is exceeded. Each helicopter has its own critical angle; this is a byproduct of its center-of-gravity.

A rolling object has a pivot point and an imaginary line extending upward from the pivot point, as the object rolls around the pivot point, the center of gravity moves closer to the pivot line. Only upon passing the pivot line will the object roll to the corresponding adjacent side of the base.

The static rollover critical angle can be determined by measuring the angle between level ground and an imaginary line drawn from skid to skid, when the helicopter's center of gravity is located on the upward pivot line.

Static rollover also pertains to automobiles. In the study of roll stability of vehicles, the static rollover threshold is a key measure. It is expressed as a lateral acceleration in gravitational units. In reality, rollovers are dynamic events, however there is a strong relationship between roll stability and occurrences of rollover in accidents.