GE, OGE and Recirculation

Wrote for the Helicopter History Site by **Glenn Beare**

In Ground Effect (IGE) is a condition where the downwash of air from the main rotor is able to react with a hard surface (the ground), and give a useful reaction to the helicopter in the form of more lift force available with less engine power required.

What is occuring is the air is impacting with the ground and causing a small build up of air pressure in the region below the rotor disk.
The helicopter is then "floating" on a cushion of air. This means that less power is required to maintain a constant altitude hover. IGE conditions are usually found within heights about 0.5 to 1.0 times the diameter of the main rotor.

So if a helicopter has a rotor diameter of 48ft, the IGE region will be about 24 - 48ft above the ground. The height will vary depending on the type of helicopter, the slope and nature of the ground, and any prevailing winds

Out of Ground Effect (OGE)

Out of Ground Effect (OGE) is the opposite to the above, where there are no hard surfaces for the downwash to react against.

For example a helicopter hovering 150ft above the ocean surface will be in an OGE condition and will require more power to maintain a constant altitude than if it was hovering at 15ft.
Therefore a helicopter will always have a lower OGE ceiling than IGE due to the amount of engine power available.

Published performance figures for a given helicopter may state something like:

Hover Ceiling at Max Weight = 4000ft OGE and 6000ft IGE.

This means that the fully loaded helicopter can hover at 4000ft above the ocean (ie. no hard surfaces close below), and can hover at 6000ft above a tall mountain top where there is the ground close below (within 0.5 - 1.0 rotor diameters).
Mountains this high are common in Papua New Guinea for example.

Recirculating

Recirculating is a condition which can occur during a low hover in ground effect.

Imagine the airflow which was directed to the ground to create the air cushion in a ground effect is now rebounding off the ground and going back up into the top of the rotor system. When it passes back through the rotor again it gets accelerated.

This process may continue with the air velocity increasing each time it passes through the rotor. Eventually the velocity is so great that the air going into the rotor from above causes a loss of lift and the helicopter will sink toward the ground unless the pilot increases power.

This means that if recirculation is occuring, the helicopter will need more power to hold a constant height.

Recirculation will not always happen but will be aggravated by the type of ground or nearby obstacles causing the air which is trying to escape out to the sides of the helicopter to be directed back up toward the rotor system.

The result is a "recirculation" of **downwash air**

Skids or wheels ?

Wrote for the Helicopter History Site by **David Gibbings** and **Taylor Cox**

Skids are used mainly because they weigh less than wheels. On larger, more powerful helicopters, wheels are used because the utility and convenience can be more important than the savings in weight. In order to move a skid-equipped helicopter on the ground, one has to attach a set of ground-handling wheels, jack up the helicopter, and roll it (into the hangar for maintenance, for example). If your helicopter already has the wheels as a permanent feature, it is more convenient to move around when the engine is shut down or the pilot has wandered off.

The design decision between retractable or fixed wheels becomes a trade-off between the complexity/weight but increased aerodynamic efficiency of retractable gear and the simplicity of fixed gear (and increased drag/reduced efficiency).

It really depends on the primary use of the helicopter; if you are logging, skids make sense because you can lift larger loads and are more concerned with hovering performance. If the primary mission is medevac or air transport, retractable wheels allow greater speed and increased fuel economy over long distances.
So the main factor is one of simplicity, a skid landing gear needs very little maintenance but there is a drawback. Ground handling is a bit more difficult, so it follows that it is the smaller machines that use them. Once you get above say 8,000lb or 4 tons, you really need some built in wheels to move the thing around, a
Bell UH-1 must be somewhere near the practical limit, especially if your trying to get it under cover in a hurry.

Rotor 's Configuration

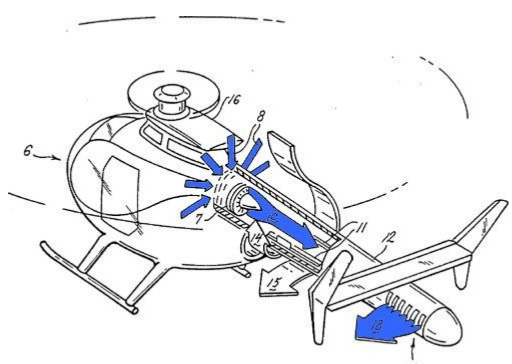
When the engine develops enough power to lift the helicopter, the main problem is how to counter the main rotor forcing the fuselage to rotate in the opposite direction of the rotor. This effect is known as **Torque**.

The classic solution was a small tail rotor to push the fuselage in the opposite direction of the torque force.

Another popular solution was tandem rotors. The primary advantage of this configuration is the ability to lift heavy loads whose position relative to the helicopter's centre of gravity is less critical than in the single rotor configuration.
Because there is no anti-torque rotor, full engine power can be applied to lifting the load.
Disadvantages of the tandem rotor system are a complex transmission and more drag due to its shape and excessive weight.
Read about drag in our "Why can't a Helicopter fly faster than it does ?" article

NOTAR

A relative new solution, the **NO TA**il **R**otor, uses jet thrust rather than blades to provide directional stability and reduce noise, providing the world's quietest helicopters.



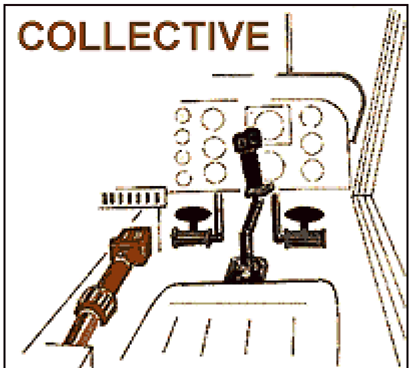
NOTAR also utilizes **Coanda Effect** with the rotor downwash across the tailboom and an internal airflow through the tailboom to produce a sideways "lift", or more correctly "thrust" to counter main rotor torque.
The jet thrust from the nozzle at the end of the tailboom is primarily used for directional control, with a very small contribution to anti-torque force.

After the torque effect, the other main problem was the **tendency of the helicopter to roll laterally in the direction of the retreating rotor blades** as the advancing blades pass through denser air and generated greater lift than the retreating blades that pass through less dense air.

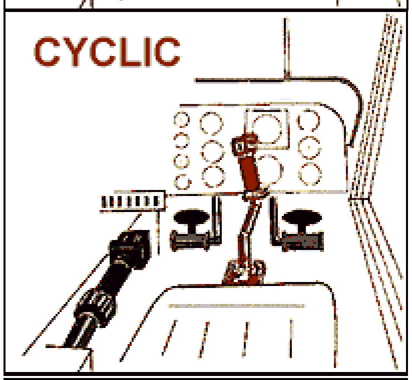
This problem was eventually solved by the introduction of a flapping hinge in the rotor head, which allowed the advancing blade to climb slightly, thereby reducing its angle of attack and the amount of lift generated, while the retreating blade fell slightly, thereby increasing is angle of attack and the amount of lift generated.

Flying a helicopter

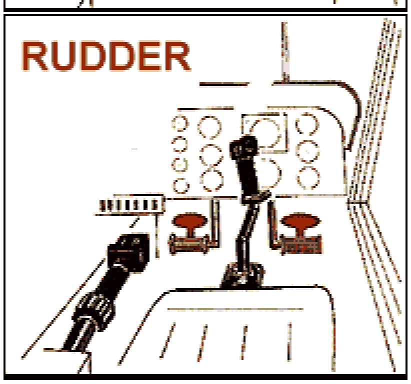
Animated pictures are a contribution of the Westland web site.
The helicopter is steered in any direction by inclining the axis of the main rotor in that direction. Flying a helicopter requires great concentration.



You must use one hand on the control lever that is at your side **(the collective control stick)** to raise or lower the helicopter, while at the same time controlling the throttle (not an easy task).
This is a control which is only found in helicopters and is linked to the engine power. Moving this up and down changes the pitch of the main rotors. As the pitch is increased more power is required from the engines so that the rotor speed is kept at the same level.



You must use your other hand on the control lever that is just in front of you **(the cyclic control stick)** to move the helicopter forward, backward and to either side, as if you were in a conventional aircraft.
Moving it forward or back will point the nose of the helicopter up or down. It does this by varying the angle of the rotor blades as they go round, tilting the rotor back and forth. When moved left or right the rotor tilts in that direction and the helicopter banks and rolls.

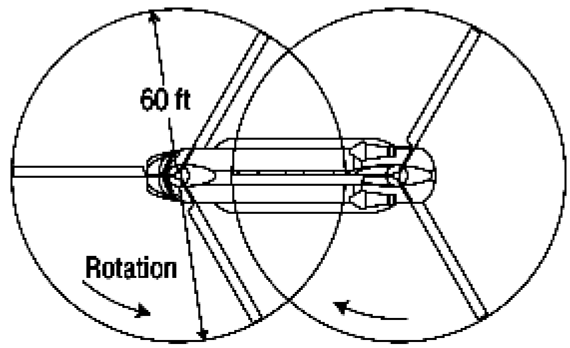


And finally you must use the tail rotor pedals, on the floor, to control the pitch of the tail-rotor. For straight flight, the pitch of the tail rotor is set to prevent the helicopter from turning to the right as the main rotor turns to the left. The pilot pushes the left pedal to increase the pitch of the tail rotor and turn to the left. Pushing the right pedal decreases the pitch of the tail rotor and turns the helicopter to the right.

Flying a helicopter requires entirely different skills than flying conventional aircraft. This is why it is difficult to fly a vertical take-off or landing (VTOL) aircraft since both skills are required when making the transition from vertical to horizontal flight.

Notice the pilot 's hands

On tandem rotors helicopters, like Boeing 's Chinook, that had not tail rotor, the pedals are connected to the swashplates and cyclicly change pitch on both rotors in equal, but opposite directions. For example, if the left pedal is pressed at a hover, the front rotor disk tips left and the rear rotor tips right so that the helicopter yaws to the left.



Two types of panels:

Ok, now take a look how it is ...

How the Helicopter Flies ...

Contribution: Sikorsky Aircraft

Flight of a helicopter is governed by the pitch or angle of its rotor blades as they sweep through the air. For climbing and descending, the pitch of all the blades is changed at the same time and in the same degree.

To Climb, the angle ot pitch of the blades is increased. To descend, the pitch of the blades is decreased. Because all blades are acting simultaneously, or collectively, this is known as **collective pitch** .

For forward, backward and sideways flight an additional change of pitch is provided. By this means the pitch of each blade increases at the same selected point in its circular pathway. This is the **cyclic pitch** .

With these two controls in mind let us make an imaginary flight. With the engine warmed up and the rotor blades whirling above us in **flat pitch**, that is, with no angle or bite in the air, we are ready to start.

We increase the collective pitch. The rotor blades bite into the air, each to the same degree, and lift the helicopter vertically.

Now we decide to fly forward. We still have collective pitch to hold us in the air and we adjust the cyclic pitch so that as each blade passes over the tail of the helicopter, it has more bite on the air than when it passes over the nose. Naturally the helicopter travels forward.

Now we decide to stop and hover motionless so we put the cyclic pitch in neutral, the rotor blades now have the same pitch throughout their cycle, and the collective pitch holds the helicopter suspended in space without moving in any direction.

In short, it is the cyclic and collective pitch which gives the helicopter its unique ability to fly forward, backwards, sideways, rise and descend vertically and hover motionless in the air , **making it one of the most versatile vehicles known by man** .

Blades and Lift

Wrote for the Helicopter History Site by **Taylor Cox**
*(Thanks to **Butch Lottman**)*

All rotor systems are subject to **DISSYMETRY OF LIFT** in forward flight. At a hover, the lift is equal across the entire rotor disk. As the helicopter gains airspeed, the advancing blade develops greater lift because of the increased airspeed (for example, if your blades at a hover move at 300 knots and you fly forward at 100 knots, your advancing blade is now moving at a relative speed of 400 knots and your retreating blade is moving at 200). This has to be compensated for in some way, or the helicopter would corkscrew through the air doing faster and faster snap rolls as airspeed increased.
(*See also "Why can't a Helicopter fly faster than it does ?" article*)
Dissymetry of lift is compensated for by **BLADE FLAPPING** . Because of the increased airspeed (and corresponding lift increase) on the advancing blade, it flaps upward. Decreasing speed and lift on the retreating blade causes it to flap downward. This **INDUCED FLOW** through the rotors system changes the angle of attack on the blades and causes the upward-flapping advancing blade to produce less lift, and the downward-flapping retreating blade to produce a corresponding lift increase. Kinda spooky, huh? Anyway, it all balances out and the lift is equal across the disk.
In a two-bladed system (
AH-1, UH-1, TH-57) it is easy to visualize this because of the Bell/Textron insistance on the semi-rigid, underslung, see/saw type rotor system. If you push down on one blade, the other one goes up like a teeter-totter. Most three or four bladed systems (TH-55, OH-6, MD500) are "fully articulated" in that each blade can flap independently, without affecting the other blades. The advancing blade still flaps upward and the retreating blade still flaps downwards, they just do so without worrying about what the other blades are doing. A rigid rotor system (
BO-105, BK-117) have the blades fixed rigidly to the hub and compensate for dissymetry of lift by **BLADE FLEXING** . The blades still flap up and down like all the other helicopters, they just do so without hinges (really spooky). The advantage of the rigid hub is that you don't have to worry about mast bumping and the helicopter is (theoretically) fully aerobatic.
The
OH-58D has a "four-bladed-soft-in-plane" rotor system, but you don't want me to go there.
There are several trade-offs one has to make when designing or buying a helicopter. I would much rather have a rigid or fully-articulated system, because they are more maneuverable and more forgiving of abrupt (Panic!) control inputs. Most mechanics and owners/operators like the Bell rotorhead because it is easier and cheaper to maintain. Things like max gross weight vs. empty weight (cargo capacity) are much more important to determining the "quality" of lift than the number of blades.
In any event, the four aerodynamic forces of lift, weight, thrust and drag all come into play, but you have to be careful when defining your terms.

- Taylor Cox Web Site
- Butch Lottman Web Site

The weight of a helicopter is divided evenly between the rotor blades on the main rotor system. If the helicopter weighs 5000 lbs and it has two blades, then each blade must be able to

support 2500 lbs and so on. The more blades a helicopter has then the lower the weight that is carried on each blade compared to the same helicopter with less blades.
In addition to the static weight of the helicopter, each blade must be able to accept enormous aerodynamic loads as well. For example if a helicopter pulls up in a 2g manouvre (2 x the force of gravity), then the effective weight of the helicopter doubles due to gravitational pull.
During a helicopter take off, the pilot causes the pitch angle on the rotor blades to increase slowly until it reaches a point where the lift being developed by the main rotor system (not each blade) is greater than the weight of the helicopter. At this point the helicopter will rise from the ground and will continue to rise until the lift force is decreased to a point where it is equal to the weight. The helicopter will then hover at a fixed height.
When the pilot wants to descend he will reduce the pitch angle so that the helicopter weight is greater than the lift force, the helicopter will then come down due to gravity.

Contribution: *Glenn Beare*

FAQ Update

What is the average flying hours before the rotorblades are due for repair ?

Most metal blades have a fixed life or **TBO** *(Time Before Overhaul)* , which is typically in the range of 3000 to 6000 hours. The average time between repair varies greatly depending on the type of operation.

Where and who are the rotorblade repair centers in the world ?

All the airframe manufacturers have their own blade repair/overhaul facilities. In addition to this, there are several manufacturer appointed service centres which are capable of doing blade repairs.

Some claimed that to buy new rotorblade is cheaper than repairing it. To what extend this statement is true ?

Rotor blades are expensive items and therefore any minor damage will be repaired. However, certain damage, especially damage to the blade spar may be impossible to repair. As blades are flight critical parts, no compromises can be accepted when carrying out repairs.

Continue with the following articles

Frequently Asked Questions

How many helicopters are there in the world ?

Approximately the world helicopter fleet at the begining of the 21st century was :

Civil (about 26500 helicopters)
46.1% in North America
18.2% in Europe
12.7% in former Soviet Union
12.3% in Asia/Pacific
7.2% in South America
3.4% in the Middle East.
0.1% in Africa

Military (about 29700 helicopters)
33.5% in North America
21.1% in Europe
16.6% in former Soviet Union
13.6% in Asia/Pacific
6.3% in the Middle East.
4.5% in Africa
4.4% in South America

Which is the cost to become a pilot ?

There a several factors (type, country) and would depend on what your goals / intentions are, but approximately us$ 8500 and will take around 5-7 weeks to complete.
Read an article about flight training considerations in our featured section.

What kinds of fuel are used in helicopters ?

Most turbine powered aircraft, ie Jet Ranger, Huey, Bell 206, all use Jet Fuel (the same as an airliner) called JET A, JET A-1 or MIL Specs JP-4, JP-5, JP-8.
Piston powered aircraft use typical civilian av-gas (high octane AVGAS)

How much does the average helicopter cost to run per hour in fuel ?

Fuel cost/consumption is an important element of operational cost, but to get a true picture of operational cost you need to include the amortized costs related to maintenance.
For example the estimated cost of operation per hour for a Bell 206B is about $192; only $42 of that is fuel.

Which is the electrical power source (AC or DC) of helicopters ?

Todays aircraft usually all use AC power, 115 volts, 3 phase,(either four wire, or three wire.) 400 cycle. Higher voltage allows less current, smaller wire, less weight, less heat. And because we live in the world of electronics today, AC is much better to control, but some equipment such as lights and some instruments still best use DC. (26volts). Therefore, most helicopters use both AC and DC. The accessory section of the x-msn (the transmission) drives AC generators which power all AC systems through a series of buses, etc.... and some of that energy is converted into DC through converters and they also have an all-purpose battery much like that of a car, for using electrical systems during system checks, and little applications without having to start and run the A.P.U. (auxiliary power unit) or engines.

Why do you pilot a helicopter from the right hand seat, while in a plane it is from the left hand seat ?

We can list several reasons :

- In the early days of rotorcraft development, the machines that flew then did indeed have a distinct difference in altitude between the left and right sides. The left side of the aircraft, at a hover, was considerably lower than the right side. Therefore it was determined that the right side should be the pilot's seat. If the rotor system turned in the oposite direction the effect would be reversed.

- Generally, technical reasons choose the pilot seat.
Have a look at the Robinson R22, due to the rotation of its blades, it would fly inclined on the left .

The right blade is the fastest one when flying : it speed is the rotation speed **plus** translation speed

The left have it speed equal to : rotation speed **minus** the translation speed.

Also the fuel tank is on the left side. So, the pilot has to be on the right side to equilibrate the system. On a big helicopter, this effect is minored, but on a light one as a R22, it so important that the helicopter could not fly.

- Other reason that the pilot position is on the right is because the pilot needs his right hand to fly the A/C. Since the collective doesnt need the attention that the cyclic needs its only natural to put the pilot on the right hand side, thus leaving the left hand to tune radios and perform other tasks.

- another very simple and logical answer: in earlier helicopter models, and in most of today's smaller models, having the collective stick on the left side made it awkward for the pilot to enter and exit his seat, having to step over the collective control stick either way. Thus entering and exiting from the right side made more sense. Plus, it simplified the collective control linkage system.

Read more at *Flying a Helicopter* in our how fly? section.

Is there any relation between the size of the helicopter and the landing pad, or is it a specific ?

The landing pad size for a helicopter is that it has to be larger than the rotor blade diameter plus the tailrotor diameter and the depth of the pad meaning the height of the trees surrounding the landing area. Next you have the weight and power remaining to determine.

E.g. if the helicopter is light, has alot of reserve power, and has to hover down into 50 foot tall trees with only 3 feet of clearance between the blades and the trees, it would fit. If the helicopter is heavy with payload and unable to hover out of ground effect the helicopter would not even attempt.