**Tactical flying machines: the Helicopters**

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Helicopters are the dragonfly of the mechanical world. You may find it puzzling why such a saying exists. But look deep into their movements. A dragonfly can fly around chasing their preys swiftly. They can fly fast and also make sharp turns. Sometimes during sudden turns, it experiences *4g* to *9g* acceleration. (See box for explanation of this.) However, the distinct feature of a dragonfly maneuver is hovering: the ability to hold the position in a leveled flight. Besides, it can fly forward, backward, upward, downward, and sideward (left and right). Humans' longing to fly, especially with great agility, made them discover one of the most effective tactical flying machines: the *Helicopters*.

**BOX Acceleration due to gravity**

We know that all objects are attracted to the Earth due to their mass. This force of attraction results in an acceleration directed towards the centre of the Earth and is called the acceleration due to Earth’s gravity (actually a small component of this force is due to the rotation of the Earth as well). This is usually labelled by the special symbol, *g*. For example, if your mass is *m*, then you are attracted to the Earth by a force (called your weight) equal to *mg*. The value of *g* is *g*=9.8*m/s*2. So, if you are being accelerated by four times that value, you are experiencing an acceleration of *4g*, etc.

**END OF BOX**

But, why do we need helicopters when there is an airplane? The first human-powered flight using an airplane happened on December 17, 1903, by the brothers **Wilbur** and **Orville** **Wright**. On the other hand, **Herman** **Ganswindt** demonstrated the first heavier-than-air motor-driven human-carrying flight in the July of 1901. However, the video footage to prove the existence of that event is lost in time.

A helicopter has mighty wings, not stationary but rotating, unlike in an aircraft. The significant advantage of helicopters comes from the *hovering* abilities. You may have seen (in movies or in real life), a helicopter taking off from the ground and just staying motionless in the air. This makes it unnecessary to take-off from a run-way. Such qualities made helicopters useful for a wide range of applications like air-lifting payloads, rescue operations, air assault, forest-fire fighting, deploying soldiers and war units on the battlefield, running supplies to remote locations like oil-wells, radio stations, etc., and many more. Even for missions on another planet, like Mars, a helicopter named **Ingenuity** is used to understand the atmosphere and terrain.

By the end of world war II in 1945, a tremendous amount of machinery was lost along with lives. Germany and the United States alone lost a combined total of 1,71,875 aircraft of different types. By then, the mass-produced operational helicopter (**Sikorsky** R-4) was just a few (around 131), and almost none were lost in a battle. Only in the Burma-India front were they deployed for the rescue operation.

My dear readers: note the timelines mentioned above carefully. For example, world war II was fought mostly with airplanes but not with helicopters despite an early discovery. So when did humans have the time to master the technology of an aircraft, how did they lag with helicopters? And when did more practical helicopters come into existence?

**Airplanes versus helicopters**

Airplanes have only **four** degrees of freedom. They can move *forward*, turn *sideways* (left or right), *roll* about their axis, and *pitch* up and down. To control these movements, there are complicated controls available in the cockpit and around the control surfaces of an airplane for only four degrees of freedom. In contrast, helicopters possess **six** degrees of freedom (they can move *linearly* in the x, y, z-directions, and *roll* about the same axes), just like a dragonfly. Think of the complex control capabilities needed to pilot a helicopter. That is why it took great engineers like **Igor** **Sikorsky** and **Wynn Laurence LePage** to develop a working machine during the 1940s. Before understanding the complexity of helicopters, one should get a grasp on how did they fly?

**How helicopters fly**

A helicopter has blades, and they are practically rotating wings. Wings are made of particular cross-sections called an *airfoil*. An airfoil splits the incoming wind smoothly on the top and bottom sections. However, part of the air on the top side travels faster than the bottom side due to the shape. As a result, quickly moving air creates a pressure drop on the top side. An imbalance in pressure produces a force to act along the direction of the pressure drop. This can lift the vehicle.

For example, a person can be sucked into a fast-moving train passing through a platform because of the low pressure in the space between them. Similarly, the way clouds are drawn towards a cyclone's centre, where the pressure is low.

When the airfoil sections are oriented towards the wind at a particular positive angle, more lift force is produced to a certain extent. Beyond a certain point, the flow on the top side separates, and the ability to create a pressure drop is lost or *stalled*. The angle at which an airfoil stall is called the *stalling angle of attack*.

Think of the blades of a fan. The central portion is moving more slowly, and the outer part of the blades are moving very fast. The same holds true for helicopter blades. As the blades are made up of airfoil sections, a non-uniform lift along the blade length is created. When the blades are provided with a mechanism to change the angle on a positive side, more lift force is generated, thereby gaining altitude. While decreasing the angle, the opposite happens. But what is limiting a helicopter from gaining altitude continuously? The question can be addressed from two fronts: *density* *altitude* and *shock* *waves*. Let us see how these affect the speed of a helicopter.

The Earth’s atmosphere is made of layers of gases stacked one over another. The lower stack, near the ground, experiences more immense pressure and density. High altitude is filled with meager gas molecules and so low pressure. As the helicopter gains altitude, there is insufficient fluid density to push the vehicle and the air cannot sustain the needed lift to balance its weight.

One could argue that the blade should rotate at higher velocity to move more fluid. However, the blade velocity increases linearly from the central hub to the tip as the rotor revolutions increase. Beyond a particular rpm (revolutions per minute) for a considered blade length, the velocity of the tip of the blade might cross the speed of sound! This is the speed at which the air molecules communicate with themselves (that’s how sound travels through air). This can cause shock waves to form. It can be associated with the hurled air after a high-speed car passes near you in a blink of an eye. When shock waves form, airflow over the blades is affected, and the helicopter begins to drop altitude.

**Helicopter controls**

How does a pilot control a helicopter that has a high-speed rotating wing? There are three flight controls in a helicopter: the cyclic, the collective, and the anti-torque control. If the blade rotates in a specific plane, let us say, parallel to the ground. Then the lift force is produced in the direction perpendicular to it to control the upward and downward motion is called the '**collective**'.

When the helicopter is hovering (stationary above ground), the **cyclic** controls the movement of the helicopter forward, backward and sideways. During forward flight, the cyclic control is similar to that in an airplane: left or right inputs cause the helicopter to roll into a left or right turn, and forward and back inputs changes the altitude, so the helicopter climbs or descends. You can see that the pilot has to stay pretty sharp to control all those directions of motion!

**The tail boom**

Every helicopter has a tail boom with a rotor. Ever wondered why? When the blades rotate in a clockwise direction, the entire body of the plane rotates in the other direction. But, of course, nobody wants such kind of uncontrolled rotation due to Newton's third law. So a long tail boom is made to counter the spin, and a rotor rotating in a plane perpendicular to the main rotor is kept at the tail boom's end. This rotor produces varying thrusts to produce the necessary **counter** **torque** (opposite rotation).

Every trained pilot knows how to direct their *copters* for the desired move. And now you see how a complex movement to gain tactical advantage always requires complex control systems in helicopters. Thus piloting a *helo* (another name for helicopters) is more demanding than driving a plane. In the modern days, we see the principles of rotating wings in different types of flying machines like gyroplanes, quadcopters (drones), tilt-rotor aircraft, and even propeller aircraft. A day not far in the future will all have a rotorcraft like a car on our balcony or roof. I hope engineering and technology are moving towards that goal sustainably and safely.