LINKÖPING UNIVERSITY

Lift generation of forward flying helicopters/rotors

Andrés Gacía López and Michael Avraham Ajzental
TMAL02, Linköping University, 2018

1 How a helicopter works?

The functioning of a helicopter is based in the Third Newton's Law, which says that for every action there is an equal opposite reaction. In the case of the helicopter, the movement of the blades creates a down airflow and with reaction is the generation of lift that takes off the aircraft. All the data references were taken from the Federal Aviation Administration [1].

1.1 Function of each rotor

Typically, a helicopter have 2 rotors, the main rotor which allows the craft to take off, fly forward, backward, and laterally; and the second one, which is called the anti-torque rotor.
The main rotor produces a torque in the cabin, and to maintain the helicopter stable the anti-torque is needed in the tail to generates lateral thrust and creates a moment against the one that is being produced by the main rotor.
The main problem of this rotor is that it produces a lateral thrust.

1.2 Blades' angles

The movement of an helicopter is based on the blades' angle.

COLLECTIVE PITCH VARIATION:
To take off, the blades have to produce more vertical force than the helicopter weight force, and this is generated by modifying the angle of attack in all the blades to get the maximum lift. The increasing of this angle generates more lift by increasing the pressure below each blade.

CYCLIC PITCH VARIATION:
The functioning of the helicopter when it is hovering depends on the pitch angle of the blades, which can make the aircraft steer in any direction by modifying it. When one side of the blades disc has a higher angle of attack than the other side, the helicopter moves to the direction where the blades have the less angle of attack.

1.3 Forward Flight

To generate the forward movement of the helicopter the cyclic pitch variation of the blades has the main function. In order to get this movement, the lift generated in the backside of the aircraft has to be higher than the front-side part.
It is obtained by increasing the backside's and reducing the front-side's angles.
When the different lift forces appear, the higher value of one of them creates a torque which inclines the resultant force of the upper part of the craft, appearing the thrust (Figure 1).

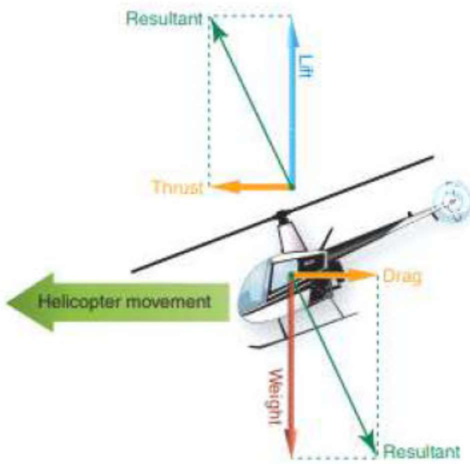

Fig. 1 . Balance of forces in an helicopter. Reference: [1]

When it starts to moves forward, the aircraft descends (lose altitude) because some of the lift is lost and transformed into thrust. Therefore, lift and weight are not equal anymore. This fact is solved with the velocity. Lift grows with the squared of the airspeed velocity, so the lift and weight forces becomes equal again. This is called **Translational Lift**. This is the reason why the aircraft climbs when it is accelerating. The acceleration of the helicopter causes the airflow on the bottom of the blades to go more horizontally and it reduces the turbulence and the appearing of vortex, a fact that is reflected in a increasing of the efficiency of the rotor disk.

2 Inconveniences of Helicopters

The angle's variations in blades is used to solve two problems of the helicopter stability: lateral thrust and dissymmetry of lift.

2.1 Lateral thrust

As it has been stated previously, the tail rotor generates lateral thrust, and it is neutralized by modifying thrust in the other direction with the angle of the blades.

2.2 Dissymmetry of lift

In forward flights, the helicopter's forward speed is equal to the velocity of the airflow, and the air flows in the opposite direction of the aircraft. The relative airflow across the blades is not the same in all the rotor disk. When rotating, there is always a time when the blade is in the same direction of the helicopter movement, has the airflow against its direction and hence an increase in its relative wind. On the other hand, in the opposite side, in its favour, reducing the helicopter's forward speed. In Figure 2 it is possible to understand that situation in a better way. The highest relative airflow in the blades occurs in the right side (point A), then it decreases until the blade is completely in the left side, where the relative wind speed is at its lowest. That happens because the blade is in the same direction of the airflow. After that, the blades continues to rotate and the relative wind speed velocity starts to increase until finally reaches again point A, repeating everything again.
Lift force generation depends on the square of the velocity. The blade in the right side of the aircraft is called Advancing Blade because when the relative wind speed reaches its maximum velocity, more lift is generated. On the other hand, the left side of the aircraft is called Retreating Blade because when the relative wind speed reaches its minimum velocity, less lift is generated. This situation is called Dissymmetry of lift, which is the unequal lift generation in the blades. This difference can make the helicopter be uncontrollable and, in counterclockwise rotation, make it roll to the left.
The way to have equal lift forces in both sides is due to blade flapping, on in other words, to change the angle of attack of the blades in each position of its rotation: In Advancing Blade, decreasing it and producing less lift; In Retreating Blade, increasing it and producing more lift. In Figures 3 and 4 it is possible to see the difference in forces of lift distribution without and with flapping, respectively.
Besides that, it is necessary to have an angle's limitation on the Retreating Blade. At higher forward speed and consequently high angle of attack, this blade can stall.

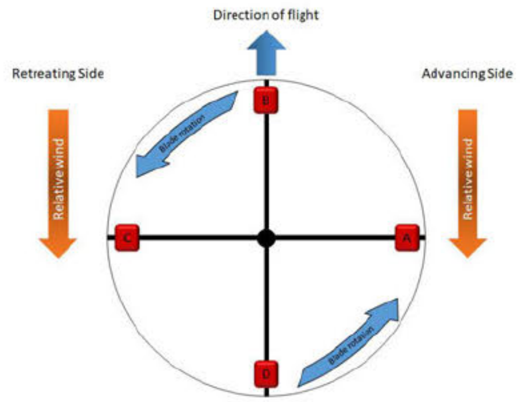

Fig. 2 . Airflow in an aircraft forward flight - top view.

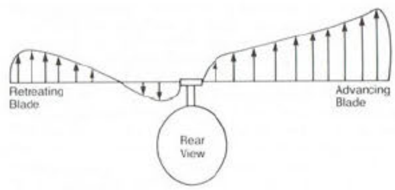

Fig. 3 . Lift distribution without flapping. Reference: [2]

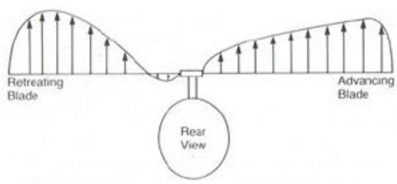

Fig. 4 . Lift distribution with flapping. Reference: [2]

Authenticity and Plagiarism

By submitting this report, the author(s) listed above declare that this document is exclusively product of their own genuine work, and that they have not plagiarized or taken advantage from any other student's work. If any irregularity is detected, the case will be forwarded to the University Disciplinary Board.

REFERENCES

[1] US Department of Transportation. *Helicopter Fliying Handbook.* FEDERAL AVIATION ADMINISTRATION, 2012.

[2] Why do helicopters not roll over when flying forwards?, 2017.
URL `https://aviation.stackexchange.com/questions/45875/why-do-helicopters-not-roll-over-when-flying-forwards`