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Lift generation of forward flying helicopters/rotors

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1 Introduction

This paper gives a fundamental introduction to the lift generation in forward flying helicopters and rotors. The paper proceeds by introducing the concept of basic lift generation in helicopters and the role of blade orientation in lift generation. Then a brief description about a forward flight of helicopters with comparison to different rotor configurations are presented to understand the lift generation influenced by the different rotor configurations. Finally the paper discusses the complexity involved in the forward flight and possibly discuss some futuristic ideas to overcome these convolutions in lift generation of forward flying helicopters.

2 Basic Aerodynamic forces

As soon as the helicopter lifts off the ground, the interaction of the geometry and velocity of the aircraft with the flow field generates four aerodynamic forces: lift, weight, drag and thrust. In helicopters, the lift force is generated due to the sudden change in direction of the fluid flow caused by the aircraft's rotor blade. The majority of this lift force is generated due to the result of decline in pressure above the rotor blade, rather than the high pressure developed at the lower surface of blade.

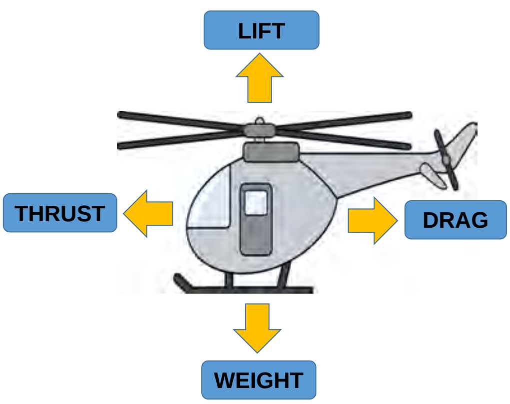

Fig. 1 *Aerodynamic forces*

The weight of the helicopter on the other hand is a fixed downward force that pulls the aircraft towards the ground due to the force of gravity. Thrust is a forward force produced by the propeller or rotor system. The tail rotor also generates a small portion of thrust, used to control the helicopter's yaw. Drag, on the other hand is a resistance force to the helicopter's movement through the air and caused mainly by the interference of aircraft components C_{Do} and lift generation C_{Di} (see Figure 1). [1]

3 Forward flight

For the helicopter to be in forward flight the main rotor must be tilted, which will induce a tilt in the coning axis backward and angled to the advancing side of the rotor. With the increasing coning angle, there will be an increment in the flapping angle. With higher flapping motions, there will be an increase in the backward tilt of the cone axis, which will boost the longitudinal force and thereby restricting the forward flight of the helicopter. So, the flapping motion is restricted by the centrifugal forces and flapping compensator. [2]

3.1 Airflow in forward flight

In forward flight, air flows opposite the aircraft's flightpath, so the velocity of the airflow is equal to the velocity of the helicopter in forward flight. However, relative velocity at each section of a blade will vary in accordance with different positions in a rotor disk. [3]

Therefore, the airflow meeting each blade varies continuously as the blade rotates. The highest velocity of airflow occurs over the advancing side of the helicopter, because the velocity of the air meeting this blade equals rotational velocity of the blade plus wind velocity resulting from forward airspeed, so the lowest airflow velocity is in the retarding side (see Figure 2). This is known as dissymmetry of lift, so if this dissymmetry were not controlled, the helicopter would be uncontrollable when there was wind. So the question is: How can avoid this dissymmetry?

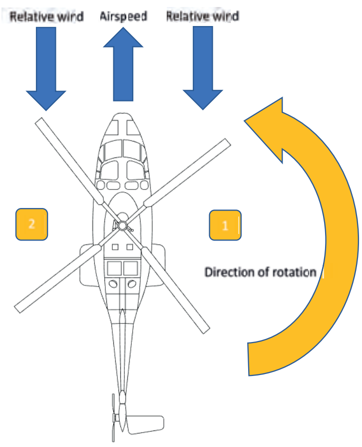

Fig. 2 *Airflow forward flight.*

The aerodynamic forces can be improved by changing the angle of attack of blades called feathering, which can be done in collective or cyclic manner. Dissymmetry of lift in the advancing and retarding side of rotor disk is compensated by coupling of cyclic feathering and flapping mechanism of the blade. [4]

In addition when the blade flaps upward (caused by the higher speed on the right side of the helicopter), the angle between the chord line and the resultant relative wind decreases. This decreases the AOA, which reduces the amount of lift produced by the blade. In this way, the helicopter is able to make an advance flight where the lift is the same throughout the helicopter.

3.2 Blade orientation in forward flight

Helicopter's blades are basically wings, so they have to change its pitch in order to vary its angle of attack and, then, generating forwards motion. There are different kinds of configurations in order to achieve these phenomena: by tilting the rotor hub or by tilting each blade. Both configurations have the same cons: (see Figure 3)

When the AOA of a blade increases, lift also increases and revolution of the rotor decreases. Thus, for a forward flight, the AOA on the advancing blades must decrease and the AOA on the retreating blades must increase.

Because of changing AOA, every blade generates different angular velocities which contributes to variation in the rotor rpm, and it should be compensated. A great solution is to generate a proportional alternation in power so that the rotor rpm keeps constant. Nowadays, a throttle control or a governor is implementing in helicopters so they can alternate its power automatically. [5]

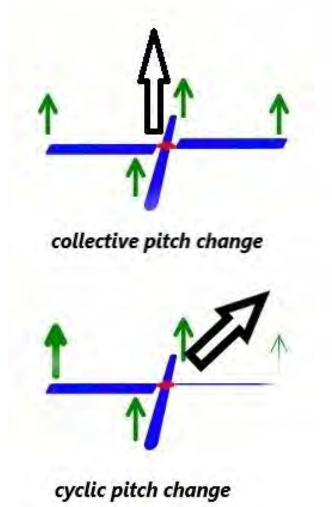

Fig. 3 *Collective and cyclic pitch.*

4 Types of rotors configuration in forward flight

There are three different configurations by which helicopters can generate thrust: semirigid, rigid and fully articulate rotor system (see Figure 4).

The semirigid configuration is capable of flying forward with a two blades mounted rigidly to the main rotor since it is free to tilt and a feathering hinge provides blades to change its pitch angle. Then, the rigid configuration is structurally complex since blades are rigidly attached to the main rotor hub. Thus, loads must be absorbed by bending as there are no hinges to do it, but the blade bending also provides the motion of the helicopter. On the other hand, this configuration is easier to design.

Finally, the fully articulate configuration lets each blade an almost free motion since it can lead, flap and feather self-reliant. On this configuration, these three degrees of freedom of each blade provides the pitch, roll and upward motion. But, this configuration is quite more complex to design than the others since blades must change constantly its pitch, yaw and roll angles while rotating in order to generate motion.[6]

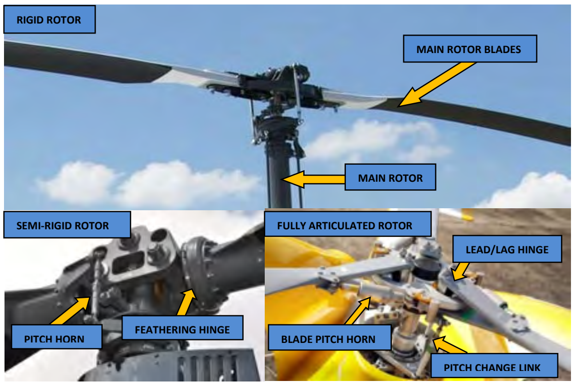

Fig. 4 *Types of rotors configuration.*

5 Conclusions

One of the major complexities in forward flight is the dissymmetry of lift, where the lift generated on the opposite sides of the rotor disc are uneven. This phenomenon of dissymmetry causes retreating blade stall, where the retreating blade experiences less airflow than expected to maintain lift. In modern helicopters to reduce the dissymmetry of lift, the mounting of rotor blades is oriented in such a way that in a rotor cycle, the angle of attack varies with the position. Even, the above-mentioned techniques of “blade flapping” and “cyclic feathering can be used to counter the dissymmetry effects.

Finally, in order to conclude this report, a forward sight in history is going to be done so that some ideas of what is coming up are projected. The futuristic innovations in helicopters focuses to infuse the ideas of lift and forward thrust. Some important research ideas include vertical take-off, hovering and attainment of fast cruise speeds by propellers in helicopters. To achieve these ideologies, the design characteristics must undergo some innovative modifications like addition of a fixed wing, box wings, larger diameter of rotors, lateral propellers, elimination of the tail rotor etc. Another major innovation is the morphing rotor blade twist geometries, which aims at the lift distribution variation along the spanwise direction without affecting the pitching moment. All these innovative ideologies signifies the vast scope for further research in lift generation strategies in forward flying helicopters/rotors.

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