LINKÖPING UNIVERSITY

# Autogyro

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## 1 Work description

The aim of this document is to describe an autogyro. The work has been divided in main architecture, where the different parts of the autogyro are explained; flight performance, where through aerodynamics flight is explained; rotor aerodynamics, in which the complexity of the rotor is described; and finally, the main control system of the autogyro.

## 2 Autogyro Description

The autogyro is an aircraft invented by the Spanish engineer Juan de La Cierva in 1923. It is classified as a rotorcraft because its lift is generated by a rotor, and it is defined as a STOL (Short Take-Off and Landing) vehicle. According to the Annex II of Basic Regulation (EC) No 216/2008 of the European Parliament and of the Council (20th February of 2008), the autogyro is inside the F category of ultralight aviation with a MTOW (Maximum Take-Off Weight) of 560 kg.

## 3 Architecture

The main parts of the autogyro are the fuselage, the stabilizers, the propeller and the rotor, all shown in the Figure 1. The fuselage joins all the components and contains the cockpit of the aircraft. There are different configurations of the cockpit, it can be covered or uncovered. The tail formed by vertical and horizontal stabilizers allows flight control. The propeller provides the forward propulsion of the autogyro. It can be allocated at the front or at the rear part of the fuselage. Apart from the propeller, the autogyro has a rotor that provides lift to the aircraft. This is the main difference between an airplane and an autogyro, so the lift is not generated by a wing but by a rotor. The rotor of the autogyro is not connected to a shaft-engine so it rotates freely by the action of the air passing through the blades. This is the main difference between an autogyro and a helicopter, in which the main rotor is powered by an engine. Due to this reason, the autogyro is not able to stop in the air or take-off and land vertically, so it needs a horizontal speed to maintain the blades rotation in order to create lift.

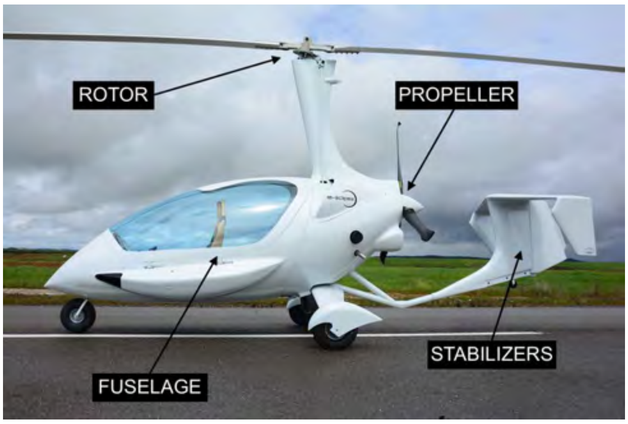


Fig. 1 . Different parts of an autogyro with the propeller in the rear of the fuselage.

## 4 Performance

The autogiro performance is based in lift creation by the auto-rotation phenomenon. To make this phenomenon take place, a flow upwards the rotor is required. This flow is achieved either with a forward motion and a backward tilted rotor or with a descending flight. [1]

### 4.1 Auto-rotation

The auto-rotation is defined as a self-sustained rotation of the rotor without any shaft torque from the engine. In this case, the power to drive the rotor comes from the relative airstream that passes through the rotor upwards due to the rotor being tilted backwards or a descending flight.
During the forward auto-rotation the regions in the rotor follow the Figure 2 shape. The dissymmetry of the right image in Figure 2 is explained below.
On the other hand, the flow distribution in the rotor tilts the lift vector as the Figure 3 shows. In the driving region (Figure 3a), the induced velocity is going upwards which entails a force component in the rotation direction, providing torque to the rotor. In the autorotation circle (Figure 3b), the lift is completely perpendicular to the rotor plane, not providing any force against the rotation motion nor favouring it. In contrast to that, the driven region (Figure 3c) takes

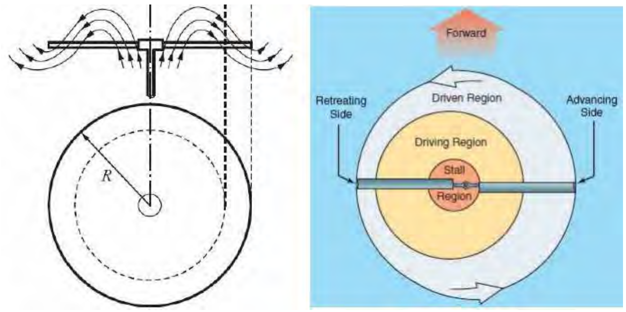


Fig. 2 . Rotor flow (left) and rotor regions in forward flight autorotation (right) [2].

an induced flow speed downwards which tilt the lift backwards creating a force against the rotor motion, creating a negative par.

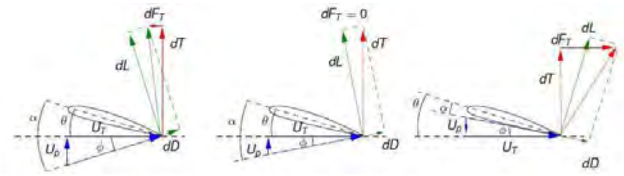

Fig. 3 . Forces in each region: a) Driving region; b) Autorotation circumference; c) Driven region

### 4.2 Aerodynamics

During forward performance, the rotor blades rotate counter-clockwise when viewed from above. Blades can be divided between ones that advance into the oncoming airflow and those which are moving away from it. The first ones occupy the semi-circle on the right-hand side of the centreline and are called advancing blades, while the retreating blades occupy the left-hand side of the rotor disc area.
The rotation velocity of the whole rotor is the same, but the difference produced by the strike or subtraction of the forward speed incident to the blades in each side of the centreline produces a variation of the airflow speed. Since the lift is related to this speed, the lift produced by the advancing blades side is higher than the other one. This phenomena produces that all driven, stall and driving regions move towards the retreating blades and then, driven area in the retracting region is smaller than the advancing blade region. This difference in the lift is known as dissymmetry of lift and produces a roll moment to the left.
This difference on the lift at both sides is avoided by hinging individually the blades, allowing them to flap up and down slightly as they move advancing to the wind or away of it. The advancing side blades decrease their lift by decreasing the angle of attack teetering up, while the retracting side blades teeter down.

During the descent in landing, the autogyro only uses the auto-rotation phenomenon using rotational kinetic energy acquired by the rotor. To do so, the pilot increases the rotor speed and then he progressively increases the collective pitch to increase the lift and reduce the vertical and forward velocity. [1]

## 5 Flight controls

In the beginning the autogyro was quite hard to control for pilots. It was equipped with a rotor, stub wings, a rudder and an elevator. The autogyro got a bad reputation amongst pilots for its tough controllability.
To get rid of this bad reputation, a new design was invented, the so called directly orientable rotor control. In this design, the rotor was placed on a universal joint, which allowed the entire rotor shaft to be tilted in any direction. In this way, the lift force could be influenced by inclining the rotor in a specific direction. The stub wings and the elevator could be eliminated in this design.
Pitch and roll are done by the directly orientable rotor control. The rudder is retained on the autogyro for yaw control. The controlling by the pilot was done by a hanging stick in the cockpit. The hanging stick increased the ability of taking good control of the autogyro.
Furthermore, the control forces were quite low. However, vibrations in the rotor made their way to the hanging stick and this made the autogyro exhausting to fly.

### 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] Leishman G J. *Principles of helicopter aerodynamics with CD extra*. Cambridge university press, 2006.

[2] Administration F A. Rotorcraft Flying Handbook. Tech. rep., U.S. Department of Transportation.