HELICOPTER LIFT TEST SYSTEM

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ABSTRACT: *This paper proposes a didactic system that can analyze the lift of a mini-helicopter. For this, the system will have the control of the blade speed of the two rotors of the helicopter as well as the angle of attack of the blades of the main rotor. The resulting lift will be measured and displayed graphically using a software application developed in LabWindows..*

KEY WORDS: Lift, angle of attack, signal conditioning, load cells, software application

1. INTRODUCTION

The lifting force or lift is the sum of all the forces generated by the movement of the fluid around a body, projected in a plane perpendicular to the main direction of flow of the fluid in which the body is immersed.
The most mentioned application of the lift is the wing of a glider or plane. However, there are many other applications as common, such as propellers for aircraft and ships, rotors for helicopters, turbine blades, sails for sailing ships and some types of wind turbines.

Although the lift suggests a lifting action (bearing up), in fact the direction of the lift does not depend on the notion of "up" and "down", and as can be seen in Figure 1 does not depend on the direction of gravitational force (weight). Specifically, negative lift refers to a downward directed force.

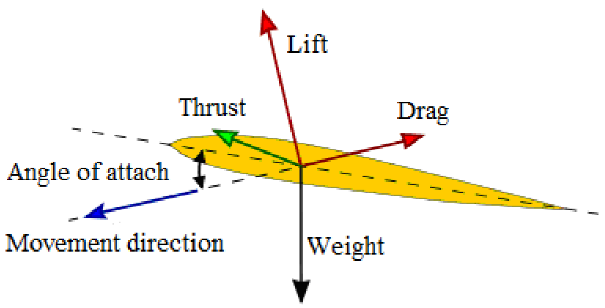

Fig.1 Lifting action

Lift is the force that holds the aircraft in the air and must be understood in relation to the other three. It can be generated by any part of the aircraft and is mainly due to the wings or blades of the propeller and in particular to the specific shape in their section. Lift is an aerodynamic force due to the "passage" of an object through a fluid. It acts on the center of pressure and is defined as perpendicular to the direction of flow of the fluid.

The lift is a mechanical force, generated by the interaction and contact between a solid and a fluid. In order to have lift, the solid body must be in direct contact with the fluid. So if there is no fluid, there is no movement.

How Helicopters Achieve a Vertical Lift

The most obvious difference between a helicopter and an airplane [1] is the ability to fly vertically, which is one of the reasons why helicopter charter residents are able to depart quickly from the heliport whenever the need arises. In most cases, the lift for an aircraft is created with its wings. For a helicopter, a lift is generated by the way the main rotor blades are formed so the air is pushed in a downward movement when the blades spin. As the air pressure changes, the helicopter lifts up.

The Role of the Second or Tail Rotor

Newton's third law of motion states that for every action there is an equal and opposite reaction, and this concept is evident in the design of helicopters [1]. As the rotors spin with great force, it affects the stability of the entire helicopter and causes it to want to spin in the opposite direction. For this reason, a second large rotor or tail rotor is added to the helicopter that serves as a counter balance. In addition to helping to keep the helicopter steady, this secondary rotor also plays a role in how the helicopter is steered during an on air tour.

Once a helicopter leaves the ground, it is acted upon by four aerodynamic forces; thrust, drag, lift, and weight. Understanding how these forces work and knowing how to control them with the use of power and flight controls are essential to flight. They are defined as follows and show in figure 2 [2]:

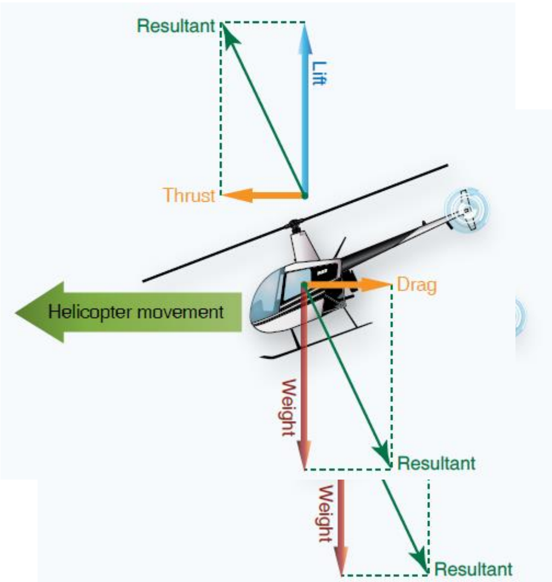

Fig. 2 Four forces acting on a helicopter

Lift—opposes the downward force of weight, is produced by the dynamic effect of the air acting on the airfoil and acts perpendicular to the flightpath through the center of lift.

Weight—the combined load of the aircraft itself, the crew, the fuel, and the cargo or baggage. Weight pulls the aircraft downward because of the force of gravity. It opposes lift and acts vertically downward through the aircraft's center of gravity (CG).

Thrust—the force produced by the power plant/ propeller or rotor. It opposes or overcomes the force of drag. As a general rule, it acts parallel to the longitudinal axis. However, this is not always the case, as explained later.

Drag—a rearward, retarding force caused by disruption of airflow by the wing, rotor, fuselage, and other protruding objects. Drag opposes thrust and acts rearward parallel to the relative wind.

How Control the Helicopter

Pilots learn how to control the helicopter by altering the angle and speed of the rotors. To hover, the pilot must balance the weight of the helicopter with the amount of force generated by the lift. This is done by altering the angle at which the blades are at as they hit the oncoming air during the spins. Helicopters can also be steered to go backwards and sideways as well as forwards

Rotor speed also controls lift—the higher the revolutions per minute (rpm), the higher the lift. However, the pilot will generally attempt to maintain a constant rotor rpm and will change the lift force by varying the angle of attack.

The system uses a Dargon mini-helicopter with two rotors, one with a fixed angle of attack of the blades and one with an angle of attack that can be adjusted using a servomotor. The helicopter used is shown in figure 3

Fig. 3 Used helicopter for test

2. THE PROPOSED SYSTEM

The proposed system is one that has the possibility of independently adjusting the speed of the two rotors in opposite directions to compensate for the effect due to Newton’s third law of motion. The system also allows the control of the angle of attack of the blades for the main rotor and measures the resulting lifting force in various control modes of the helicopter. Load measurement is performed by determining the ascendent force using load cells. The block structure of the system is shown in the following figure 4.

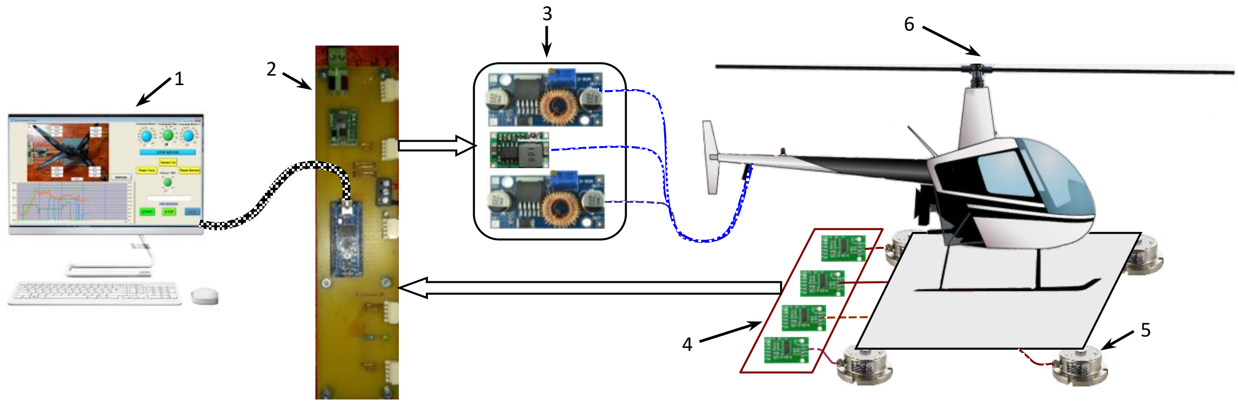

Fig. 4 The structure of helicopter lift test system

where
1- PC for running the software application
2- Measurement and control module
3- Helicopter engine control module
4- Sensor conditioning module
5- Force measurement sensors (load cells)
6- Elicopter

The helicopter motor control module has two types of circuits, one for controlling the speed of each rotor and one for controlling the angle of attack of the main rotor blades. To control the angle of attack the helicopter uses a servomotor, the control circuit uses a digital command line directly from the measurement and control module and an adjustable power supply step down module with a maximum output current of 2A shown în Figure 5.

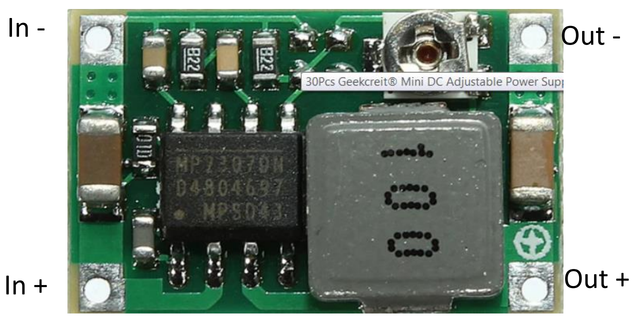

Fig. 5 Adjustable Power Supply Step Down Module

To control the speed of the two rotors, the helicopter uses 2 DC motors, the power circuit uses an adjustable power supply step down module with an output current of up to 5A and a MOSFET transistor to implement a PWM control. Adjustable power supply step down module shown in Figure 6 uses the XL4005 integrated circuit.

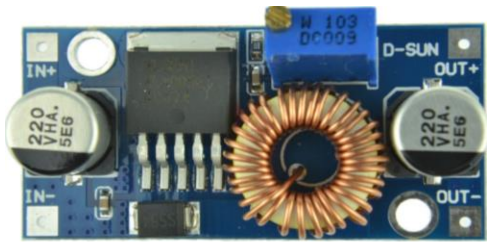

Fig. 6. Adjustable Power Supply Step Down Module

Using such a solution the speed of the 2 rotors can be controlled independently and also the maximum speeds of each rotor can be adjusted independently. A platform on which the helicopter is fixed was used to measure the lift. This platform was placed on 4 load cells

A **load cell** [3] is a force transducer. It converts afoece such as tension, compression, pressure, or torque into an electrical signal that can be measured and standardized. As the force applied to the load cell increases, the electrical signal changes proportionally. The most common types of load cell used are strain gauges.

Strain gauges load cells are the kind most often found in industrial settings. It is ideal as it is highly accurate, versatile, and cost-effective. Structurally, a load cell has a metal body to which strain gauges have been secured. The body is usually made of aluminum, alloy steel, or stainless steel which makes it very sturdy but also minimally elastic. This elasticity gives rise to the term "spring element", referring to the body of the load cell. When force is exerted on the load cell, the spring element is slightly deformed, and unless overloaded, always returns to its original shape. As the spring element deforms, the strain gauges also change shape. The resulting alteration to the resistance in the strain gauges can be measured as voltage. The change in voltage is proportional to the amount of force applied to the cell, thus the amount of force can be calculated from the load cell's output.

Load cells for a maximum value of 1Kg were used for the proposed system. For the signal processing from the 4 load cells were used signal conditioning modules made with the HX711 integrated circuit. HX711 [4] is a precision 24-bit analog-to-digital converter (ADC) designed for weighing scales and industrial control applications to interface directly with a bridge sensor.

The input multiplexer selects either Channel A or B differential input to the low-noise programmable gain amplifier (PGA). Channel A can be programmed with a gain of 128 or 64, corresponding to a full-scale differential input voltage of ±20mV or ±40mV respectively, when a 5V supply is connected to AVDD analog power supply pin. Channel B has a fixed gain of 32. Onchip power supply regulator eliminates the need for an external supply regulator to provide analog power for the ADC and the sensor. Clock input is flexible. It can be from an external clock source, a crystal, or the on-chip oscillator that does not require any external component. On-chip poweron-reset circuitry simplifies digital interface initialization. There is no programming needed for the internal registers. All controls to the HX711 are through the pins.

Channel A differential input is designed to interface directly with a bridge sensor's differential output. It can be programmed with a gain of 128 or 64. The large gains are needed to accommodate the small output signal from the sensor. When 5V supply is used at the AVDD pin, these gains correspond to a full-scale differential input voltage of ±20mV or ±40mV respectively. Channel B differential input has a fixed gain of 32. The full-scale input voltage range is ±80mV, when 5V supply is used at the AVDD pin.

The module diagram used is the one shown in figure 7:

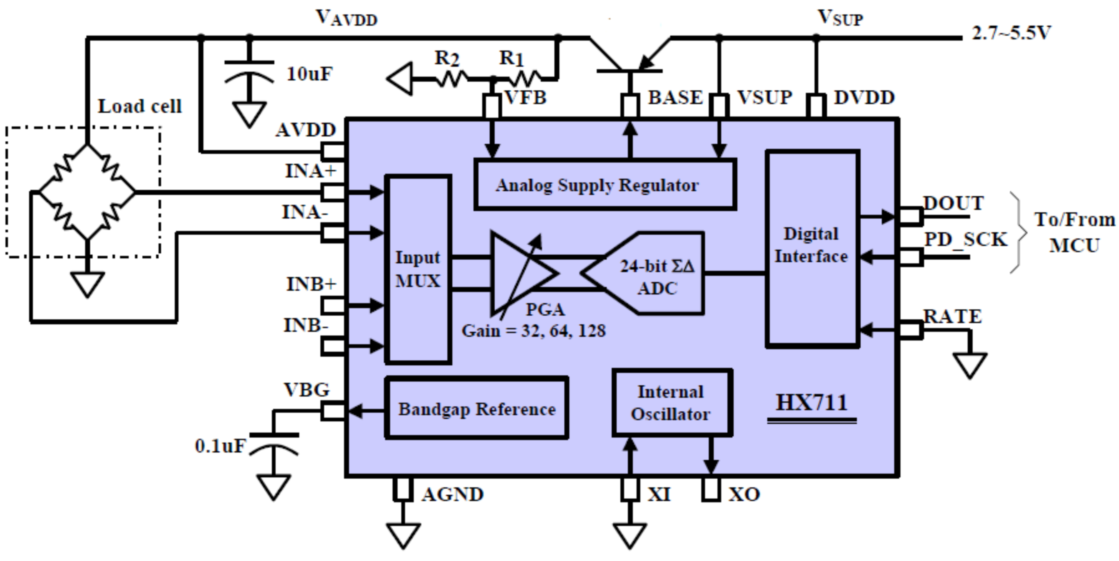

Fig. 7 HX711 using circuit

The measurement and control system is one made with an Arduino Nano and allows the implementation of two individual controls of the PWM type to control the speed of the 2 rotors, a control for a servomotor that acts on the angle of attack of the blades. The system also allows the synchronous reading of 4 circuits of type HX711 for reading the signals from the 4 load cells.

The system has implemented a communication protocol with the application running on a PC, an application made in LabWindows. From this application you can give commands to control the speed of the helicopter rotors and process the information received regarding the lift developed by the helicopter.

Software application

The software application is implemented in LabWindows and allows the independent control of the speed of each rotor by sending for the PWM control a value in the range 0-255 corresponding to a change in speed between 0 and 100%. It is also possible to control the servomotor to adjust the angle of attack of the blades corresponding to a movement of the servomotor between 0 -180. The application also has work buttons from which you can give commands to perform measurements in various situations. The Tara button allows you to measure values at a certain point in time and use these values as a reference for future tests. The working window for the software application is shown in figure 8.

Thus, before a blade rotation command, the signal given by the load cells in the initial situation representing the weight of the platform and the helicopter at rest will be measured. These values will be used later to determine the difference in various order situations from the rest situation. Both control and measured signals are plotted for easier interpretation of the results.

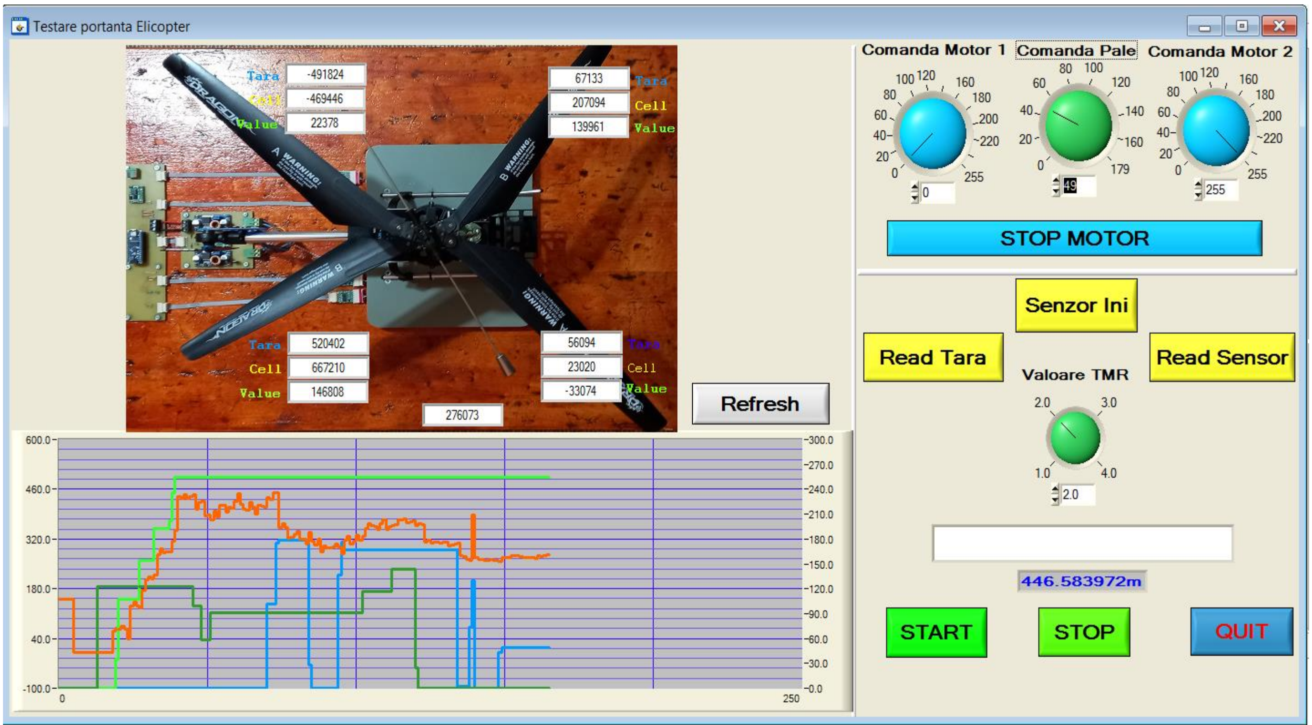

Fig. 8 Software application

3. CONCLUSIONS

Although the proposed system is relatively simple, it allows the study of the occurrence of the lifting force on a helicopter in various control modes. The measurement of the developed lift of the helicopter in 4 points allows its study in various situations by the independent control of the speed for the 2 rotors but also by observing the angle of attack on the developed lift. Independent voltage stabilizers allow the maximum permissible speed to be increased to experimentally determined values so that the model operates safely so that dangerous oscillations of the structure are not produced which could lead to its mechanical damage. For the future, an attempt will be made to place the helicopter on the measuring cells directly without using a platform and thus to be able to measure independent signals in 4 points of the helicopter.

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