SYSTEM FOR TESTING THE LIFT OF A DRONE MOTOR

Grofu Florin, Assoc. Prof. PhD

“Constantin Brâncuși” University from Târgu Jiu, ROMANIA

ABSTRACT: *This paper presents the development of a didactic system designed to experimentally determine the lift generated by a drone motor. The proposed setup enables precise control of the motor’s rotational speed, allowing for the analysis of its aerodynamic performance under various operating conditions. The lift produced by the motor–propeller assembly is measured using dedicated sensors, and the data are processed and graphically represented through a software application developed in LabWindows. This system provides an effective educational and research tool for evaluating motor performance, as well as for comparing the aerodynamic efficiency of different propeller types.*

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

1. INTRODUCTION

The concept of lift refers to the resultant aerodynamic force generated by the motion of a fluid around a solid body, projected onto a plane perpendicular to the primary direction of the fluid flow in which the body is immersed. This force arises due to pressure differences and variations in flow velocity over the body’s surface, as described by Bernoulli’s principle and the laws of fluid dynamics.

The most widely recognized application of lift is found in the wings of gliders and airplanes, where it serves as the fundamental mechanism enabling flight. Nevertheless, the phenomenon of lift extends far beyond fixed-wing aircraft. It also plays a crucial role in numerous other applications, such as the propellers used in both aircraft and marine vehicles, as well as the rotors of helicopters and unmanned aerial vehicles (UAVs), commonly referred to as drones.

Understanding and accurately measuring lift is therefore essential not only in the field of aeronautical engineering but also in emerging areas of research and development related to autonomous flight systems and advanced propulsion technologies.

Drone Control Principles

A drone, also known as an unmanned aerial vehicle (UAV), is controlled through a combination of **hardware**, **software**, and **control algorithms** that manage its motion and stability in three-dimensional space. The control system typically regulates four main parameters, known as the **control axes**:

1. **Roll** – controls the tilt of the drone to the left or right, enabling lateral movement.
2. **Pitch**– controls the tilt forward or backward, allowing forward and backward motion.
3. **Yaw**–controls the rotation around the vertical axis, changing the drone’s heading direction.
4. **Throttle**–controls the overall lift by adjusting the speed of all motors simultaneously.

Each of these movements is achieved by varying the rotational speed of the drone’s motors and propellers. For example, increasing the speed of the opposite pair of propellers increases roll or pitch, while changing the relative speeds of clockwise and counterclockwise propellers controls yaw.

2. THE PROPOSED SYSTEM

The proposed system is designed to experimentally determine the lift generated by a drone motor under controlled operating conditions. It allows precise adjustment of the motor’s rotational speed across the full operating range, from 0% to 100%, and enables accurate measurement of the resulting lift force. The proposed system are illustrated in the block diagram shown in Figure 1

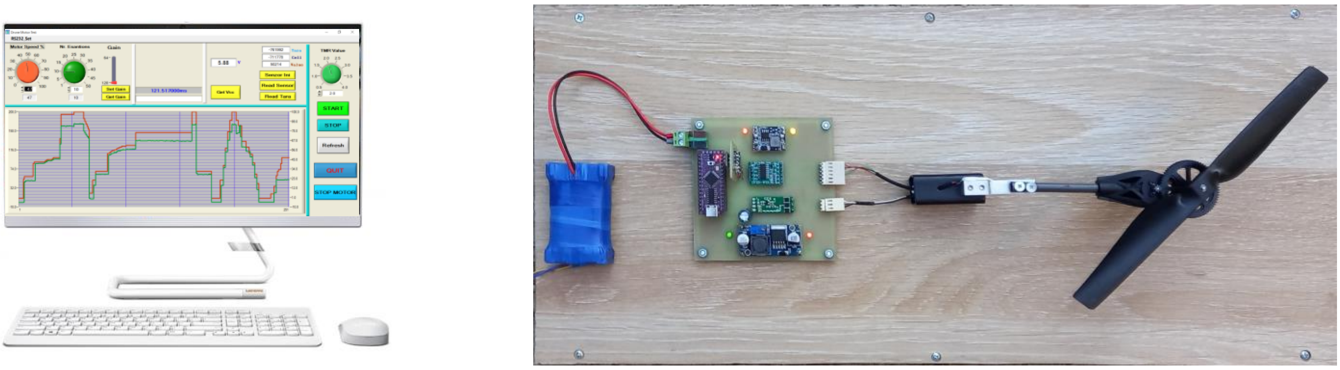

Fig. 1 Proposed System

Lift is determined by measuring the upward force produced by the propeller using a load cell functioning as a force transducer. The analog signal generated by the load cell is amplified and converted into a digital signal using a dedicated electronic module, the HX711. The digitized data are then processed by a microcontroller, which communicates wirelessly with a computer interface for data visualization and analysis.

The drone motor is a brushless DC (BLDC) motor driven by an Electronic Speed Controller (ESC) module. The ESC receives a pulse-width modulation (PWM) signal generated by the control unit and adjusts the motor’s rotational speed accordingly. This configuration ensures smooth, linear, and stable speed regulation, which is essential for obtaining precise lift measurements.

The acquired data are displayed and recorded in a LabWindows-based software application, which provides both numerical readings and graphical representations of lift as a function of motor speed. This feature allows users to analyze motor performance, evaluate propeller efficiency, and compare the aerodynamic characteristics of different types of propellers [10].

The overall structure and functional interconnections of the proposed system are illustrated in the block diagram shown in Figure 2, which depicts the main hardware and software components involved in the measurement process.

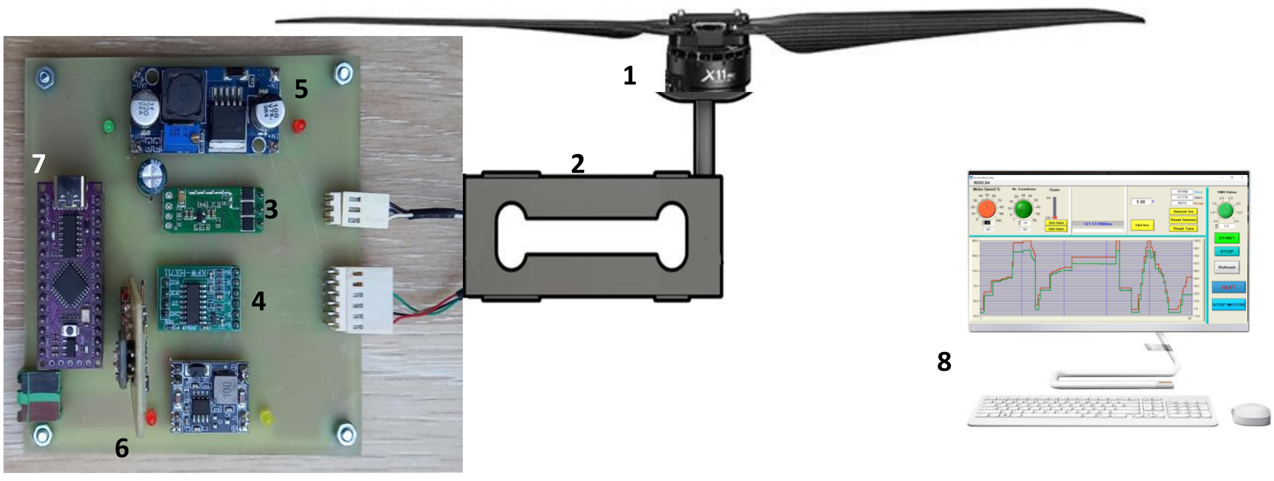

Fig. 2 The structure of proposed system

where
1- Drone motor
2- Force measurement sensors (load cells)
3- Motor electronic speed control (**ESC**)
4- Sensor conditioning module
5- Adjustable power supply
6- Wifi communication module
7- LGT8f328P microcontroller board
8- PC for running the software application

The control module for the sensorless BLDC drone motor is illustrated in Figure 3. It is powered by an adjustable step-down voltage regulator, which allows the motor supply voltage to be set between 2 V and 8 V, enabling precise control of the motor's operating conditions.

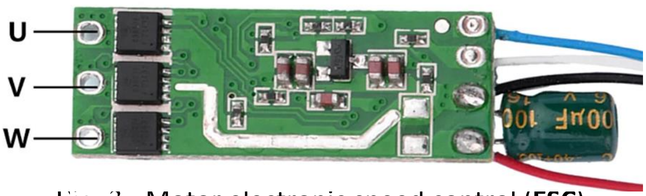

Fig. 3. Motor electronic speed control (**ESC**)

The Electronic Speed Controller (ESC) module receives a pulse-width modulation (PWM) signal from the microcontroller, which dictates the desired motor speed. By varying the duty cycle of the PWM signal, the ESC adjusts the motor's rotational speed accordingly. This configuration provides smooth, linear, and stable motor control, which is critical for obtaining accurate lift measurements.

The ESC are connected to the microcontroller, which manages both the motor speed commands and the acquisition of sensor data. The microcontroller processes the digital output from the HX711 load cell module and communicates wirelessly with the computer interface, where the measured lift values are displayed in real time using the LabWindows-based software application.

This setup ensures synchronized control and measurement, allowing the system to precisely evaluate the lift generated by the propeller at various motor speeds while maintaining stable operating conditions for the BLDC motor.

Adjustable power supply step down module shown in Figure 4 uses the XL4005 integrated circuit.

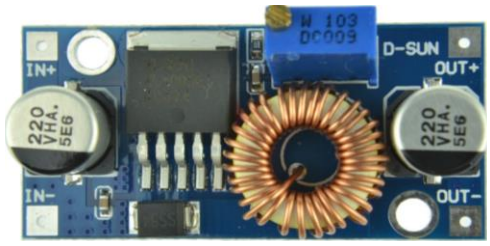

Fig. 4. Adjustable Power Supply Step Down Module

The XL4005 is a 300KHz fixed frequency PWM buck (step-down) DC/DC converter, capable of driving a 5A load with high efficiency, low ripple and excellent line and load regulation. Requiring a minimum number of external components, the regulator is simple to use and include internal frequency compensation and a fixed-frequency oscillator. The PWM control circuit is able to adjust the duty ratio linearly from 0 to 100%. An enable function, an over current protection function is built inside. When short protection function happens, the operation frequency will be reduced from 300KHz to 60KHz. An internal compensation block is built in to minimize external component count.

Load Cell and HX711 Module

The lift generated by the drone motor is measured using a load cell with a maximum capacity of 300 g, which functions as a precise force transducer. The load cell [3] converts the mechanical force produced by the propeller's lift into an analog electrical signal. To ensure accurate measurement, the analog output is amplified and conditioned before being digitized.

For this purpose, a dedicated HX711 module is used. The HX711 is a high-precision 24-bit analog-to-digital converter (ADC) specifically designed for load cell applications. It amplifies the small voltage changes produced by the load cell and converts them into digital signals suitable for processing by a microcontroller.

The microcontroller reads the digitized data from the HX711 module and performs necessary filtering and calibration procedures to obtain accurate lift values within the 0–300 g range. These measurements are then transmitted wirelessly to the computer interface, where they are visualized and analyzed using the **LabWindows-based software application**.

This combination of a 300 g load cell and the HX711 module provides a reliable and precise method for measuring lift, enabling the system to evaluate motor performance and the aerodynamic efficiency of different propeller types under controlled conditions.

The schematic of HX711 [4] is shown in figure 4:

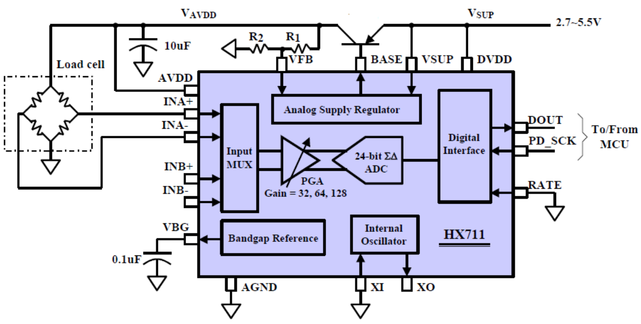

Fig. 4. HX711 circuit

The measurement and control system is implemented using an LGT8f328P microcontroller module [5], which provides the capability to simultaneously manage motor control and lift measurement. The microcontroller generates the pulse-width modulation (PWM) signal required by the ESC module to control the rotational speed of the BLDC drone motor, allowing precise and stable adjustment across the entire operating range.

Wireless Communication Module

The communication between the software application and the hardware system is established through a pair of JDY-40 wireless modules, which operate in the 2.4 GHz ISM frequency band. These modules provide a reliable wireless link with an effective communication range of up to 120 meters in open space, making them suitable for laboratory and experimental applications that require real-time data transmission.

The JDY-40 modules [8] use a Universal Asynchronous Receiver–Transmitter (UART) serial interface, which simplifies integration with microcontroller-based systems [9,11] such as the LGT8f328P used in this project. This serial interface allows straightforward communication setup, requiring only basic configuration of parameters such as baud rate, parity, and stop bits. Because of their simplicity, JDY-40 modules eliminate the need for complex networking protocols, making them ideal for short-range, low-latency communication.

In this system, one JDY-40 module is connected to the microcontroller unit (MCU) on the hardware platform, while the second module interfaces with the PC application developed in LabWindows. The modules establish a transparent serial link, enabling bidirectional data exchange. Control commands such as speed settings for the ESC are transmitted from the PC application to the hardware unit, while measurement data from the HX711 load cell module are sent back to the PC in real time.

This wireless communication setup ensures stable and continuous data flow without the need for physical connections, reducing electrical noise and improving operational flexibility. The low power consumption and robustness of the JDY-40 modules make them an efficient solution for educational and experimental systems requiring accurate, low-latency wireless control and measurement.

JDY-40 modules is shown in figure 5:

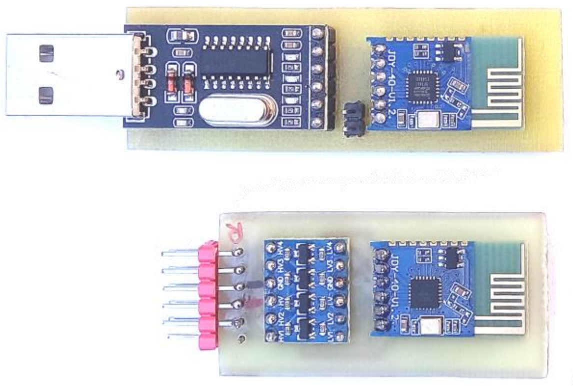

Fig. 5. JDY-40 modules

3. SOFTWARE APPLICATION

The system incorporates a communication protocol with a PC-based application developed in LabWindows, enabling real-time interaction between the measurement and control hardware and the software interface. Through this application, the user can send commands to adjust the rotational speed of the BLDC motor via the ESC, while simultaneously receiving data regarding the lift produced by the propeller.

The software processes the incoming measurements from the HX711-load cell system, performing necessary calculations, filtering, and calibration to ensure accurate lift values. These values are then displayed both numerically and graphically, allowing the user to visualize the relationship between motor speed and generated lift in real time.

This bidirectional communication framework ensures synchronized operation of the control and measurement subsystems, facilitating precise experimental evaluation of motor performance, propeller efficiency, and the aerodynamic characteristics of different propeller types under controlled conditions.

Before issuing any commands to rotate the propeller blades, the signal from the load cell is measured in the initial state (tare), which corresponds to the weight of the platform and the motor at rest. These baseline measurements serve as a reference and are subsequently subtracted from the readings obtained during various motor operating conditions to calculate the net lift generated by the propeller.

The software application processes these values in real time, providing both numerical data and graphical representations of lift as a function of motor speed or time. This approach allows for immediate visualization of the system's performance and facilitates comparison between different propeller types or operational scenarios.

The working interface of the LabWindows-based software application is presented in Figure 8, illustrating the main controls for motor speed adjustment, real-time data visualization, and graphical monitoring of the lift measurements.

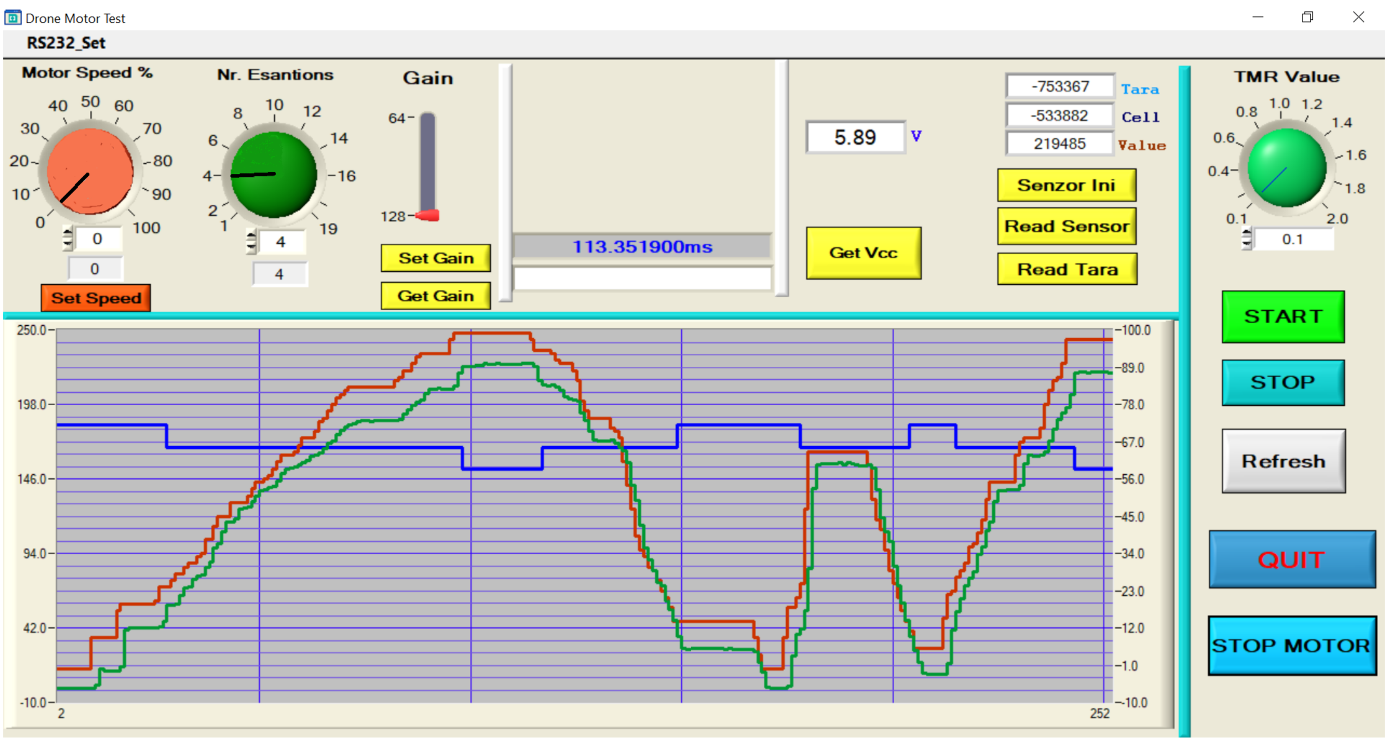

Fig. 8 Software application

3. CONCLUSIONS

Although the proposed system is relatively simple, it enables the study of lift generation in a drone motor. Measuring the lift produced allows the motor to be analyzed under various conditions by controlling its rotational speed at different supply voltages and by evaluating the corresponding lift.

The adjustable voltage regulator allows the maximum motor speed to be increased up to experimentally determined values, ensuring that the model operates safely and preventing dangerous oscillations of the constructed platform that could lead to mechanical damage.

The proposed system can also be used to test different propeller profiles in order to determine configurations that generate maximum lift, making it a versatile tool for both educational and experimental investigations of drone propulsion and aerodynamics.

4. REFERENCES

[1]. https://libertyhelicopter.com/how-does-a-helicopter-work/

[2]. Aerodynamics of Flight - Helicopter Flying Handbook (FAA-H-8083-21B) Chapter 2

[3]. https://en.wikipedia.org/wiki/Load_cell

[4]. 24-Bit Analog-to-Digital Converter (ADC) for Weigh Scales SparkFun Load Cell Amplifier-HX711 - SEN-13879

[5]. https://wolles-elektronikkiste.de/en/lgt8f328p-lqfp32-boards

[6]. Pulse Width Modulation for Power Converters: Principles and Practice, Wiley-IEEE Press; ISBN-13 : 978-0471208143

[7]. Forces Acting on the Helicopter - Flight Mechanic-https://www.flight-mechanic.com /forces-acting-on-the-helicopter/

[8]. https://benjemmett.com/archives/790

[9]. Gîlcă Gheorghe, Automatic Safety Vehicle Control Based On Arduino Microcontroller, Annals of 'Constantin Brancusi' University of Targu-Jiu. Engineering Series / Analele Universităţii Constantin Brâncuşi din Târgu-Jiu. Seria Inginerie, 2017, Issue 4, p108, ISSN 1842-4856

[10].Runceanu Adrian, Popescu Marian Ion , SOME DATABASE MANAGEMENT TOOLS FOR DATA MODELING AND REVERSE ENGINEERING, Fiability & Durability / Fiabilitate si Durabilitate, 2023, Issue 1, p143, ISSN 1844-640X

[11]. Gîlcă Gheorghe, State Of The Art In Hexapod Robots, Fiability & Durability / Fiabilitate si Durabilitate, 2023, Vol 32, Issue 2, p78, ISSN 1844-640X

[12]. Adrian Runceanu, Adrian Balan, Laviniu Gavanescu, Marian-Madalin Neagu, Cosmin Cojocaru, Ilie Borcosi, Aniela Balacescu, Enhancing the Learning Experience with AI,

[13]. Adrian Runceanu, Adrian Balan, Laviniu Gavanescu, Marian-Madalin Neagu, Cosmin Cojocaru, Ilie Borcosi, Aniela Balacescu "Enhancing the Learning Experience with AI", Information, ISSN: 2078-2489

[14]. Marian Ionescu, Ilie Borcosi "Using Raspberry-Py For Energy Monitoring Of Buildings" Annals of 'Constantin Brancusi' University of Targu-Jiu. Engineering Series / Analele Universităţii Constantin Brâncuşi din Târgu-Jiu. Seria Inginerie, 2023, Issue 1, p50, ISSN 1842-4856