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Designed of Onboard Electronics for the Construction of Unmanned Aerial Vehicle (UAV)

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Abstract

Background: This research work presents the designed and implementation of onboard electronics for the construction of fixed wing unmanned aerial vehicle (UAV), which are more properly known as drones. Basically, a drone is a flying robot. Working in combination with GPS, the flying machine may be remotely controlled or can fly autonomously by software-controlled flight plans in their embedded systems.

Method: The materials used in this designed of onboard electronics includes, Electric speed controller ESC, power supplies, remote control receiver, Electric servos (4), autopilot for Autonomous flight, electric motor/propeller, and Motorcarlc software for the simulation. The simulation was done.

Results: Results shows that the lipo (lithium polymer) battery has a load, weight, energy, minimum flight time, maximum flight time, total capacity and used capacity of 0.8ºC, 1500 g, 244.2 Wh, 59.0 minutes, 77.4 minutes, 22000 mAh, and 18700 mAh respectively. And also, the motor at optimum efficiency generate current, voltage, Resolutions, electric power, mechanical power, and efficiency of 6.45 A, 11.05 V, 14079 rpm, 71.2 W, 58.5 W, and 82.1 % respectively. Also, the motor at maximum efficiency generate current, voltage, Resolutions, electric power, mechanical power, efficiency and estimated temperature of 19.01 A, 10.95 V, 11091 rpm, 208.2 W, 146.0 W, 70.1 % and 77 °C respectively. Also, the propeller has a static thrust, resolution, stall thrust, avail thrust at 0 km/h, pitch speed, tip speed, and specific thrust of 1017 g, 11091 rpm, 788 g, 27.8 oz, 101 km/h, 425 km/h and 3.78 g/W respectively. Also, the total drive was observed to have a drive weight, power weight, thrust-weight, maximum current, power in at maximum, power out at maximum, maximum efficiency and torque of 1763 g, 148 W/kg, 0.71:1, 19.01 A, 211.0 W, 146.0 W, 69.2 %, and 0.13 Nm respectively. And finally, the aircraft was observed to has a total weight, wing load, cubic wing load, estimated stall speed, estimated level speed, and estimated rate of 1430 g, 31 g/dm², 4.5, 26 km/h, 64 km/h, and 4.0 m/s respectively.

Conclusion: The result shows that the designed onboard electronics is capable of Autonomously hovering and can stabilize the UAV.

Keywords: Onboard Electronics, Unmanned Aerial Vehicle (UAV), Flying Machine

Introduction

Unmanned aerial vehicles (UAV) are more properly known as Drones. Basically, a drone is a flying robot. Working in combination with GPS, the flying machine may be remotely controlled or can fly autonomously by software-controlled flight plans in their embedded systems. Drones are most often used in military services. However, it is also used for weather monitoring, Firefighting, search and rescue, surveillance and traffic monitoring. In recent years, drones have come into attention for a number of commercial uses. In late 2013, Amazon announced a plan to use a UAV vehicles for delivery in the nearby area's future. It is known as Amazon Prime Air, it is estimated to deliver the orders within 30 minutes inside 10 miles of distance. So, it is clear that domestic usage of UAV has vast future possibility in different fields rather than military usage [1].

UAV for military use were started in the mid-1990s with the High-Altitude Endurance. Unmanned Aerial Vehicle Advanced Concept Technology Demonstrator (HAE UAV ACTD) program managed by the Defense Advanced Research Projects Agency (DARPA) and Defense Airborne Reconnaissance Office (DARO) [2]. This ACTD placed the base for the improvement of the Global Hawk. The Global Hawk hovers at heights up to 65,000 feet and flying duration is up to 35 hours at speeds approaching 340 knots [3]. The wingspan is 116 feet and it can fly 13.8094 miles which is significant distance. Motherland security and drug prohibition are the main needs Global Hawk was designed for another very successful drone is the predator which was also built in the mid-1990s but has since been improved with Hellfire missiles. "Named by Smithsonian's Air & Space magazine as one of the top ten [4].

The area of UAV has been dominated by the aerospace industries. The reason for this can be attributed to the complexity and cost of designing, constructing and operating of these vehicles. In recent year's advancement in manufacturing techniques have placed the design and construction of UAVs in the domain of the commercial civilian user. UAVs are extremely well suited for the dull, dirty and dangerous tasks encountered in performing various applications. For these tasks the primary design considerations in the design of the UAV would be the propulsion system [5].

Technological amelioration has impacted significantly social, economic and personal life, from business approaches to international wars. These transformations can be visualized by getting benefited from these technological advancements. UAV also known as remotely operated aircraft is the best example to visualize the change. UAVs do not need any pilot onboard and can be operated autonomously or remote pilot control [6]. UAV is an integral part of the Unmanned aerial system which incorporates UAV, communication link and ground control station. UAV overcomes the limitation of the terrestrial system in terms of accessibility, speed and reliability [7]. UAV can provide cloud-free and high-resolution images to serve the commercial applications such as agriculture, mining and monitoring. UAV was originated in defense for reconnaissance and combat purpose. Perhaps in 1916 first ever semi-automatic Aeroplan was developed (aerial torpedo). In 1933 Royal Navy used the drones for the gunnery practices. Later on, with the advent and integration of advanced navigation sensors UAV became an integral part of armed forces. The emergence of technology not only removed the limitations of UAV exercises in the military but expanded their wings in commercial applications related to agriculture, scientific activities, recreation, servile, delivering goods, photogrammetry and many more [8].

The most UAV for non- military applications are the miniand micro UAVs due to their ease of use, low cost, transportation and their capability of being used to perform surveys in different ways. This requires them to be specifically designed with cheap and reliable onboard electronics which are very light within the limit of the payload requirements. Thus, this work presents an overview of the selection, implementation and simulation of the electronics that are required to power proper and navigate the designed UAV. The aim of this work is to design and implement onboard electronic for the construction of UAV.

Materials and methods

Materials

The electronics components used in the work are:

Electric speed controller (ESC)

Power supplies e.g. battery, solar etc.

Electric motors/ propeller

Remote control

Rc flight controller

Autopilots for autonomous flight

Electric servos (4)

Power control

Methods

This research work presents a comprehensive design methodology for constructing of small-scale UAV. The systematic design procedure, which includes onboard electronics, selection of design materials and simulations (using motorcalc software) as well as experimental evaluation, is utilized to construct a fully functional UAV named fixed wing uav, various ground and flight tests will be performed to verify the feasibility and reliability of the UAV. This simple, systematic and effective methodology can be easily followed and used for building small-scale UAV onboard electronics for general research purposes. The Fig 1 below show the intensive way in which the electronics components are connected in a simple flow chart and the ability for them to perform their respective functions.

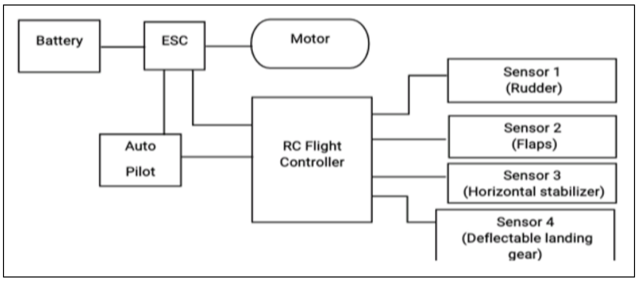

Fig 1: flow chart of onboard electronics components

Battery

Batteries are the life source of the UAV and understanding how they work will help the UAV to have long endurance. It will be connected straight to the ESC panel to power the aircraft. The type of battery used in this research work is Lipo (Lithium polymer) with a voltage of 12V, Capacitor of 25C, 3cells and with the power capacity of 2200mah.which is capable of effectively powering the aircraft for 30 minutes at least [Fig 2].

Fig 2: Examples of Lipo (Lithium polymer) battery

Electric speed controller (ESC)

Electronic speed controllers (ESCs) are devices that allow

UAV flight control lers to control and adjust the speed of the aircraft's electric motors. The ESC will be connected to the battery, the ESC will also connect the motor, the autopilot, and the RC flight controller. A signal from the flight controller will cause the ESC to raise or lower the voltage to the motor as required, thus changing the speed of the propeller. This article focuses on the small UAV, normally equipped with brushless DC motors. Motors of this type require careful and continuous regulation of speed and of the relative direction of rotation; in some cases, the possibility of implementing a real dynamic brake is needed as well. The circuit responsible for these functions is the ESC (Electronic Speed Controller), which is typically composed of a power supply stage, a circuit for detecting the current, an autopilot, Electric motor and a communication interface with the flight controller [Fig 3].

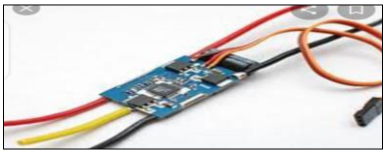

Fig 3: ESC

Electric motors/propellers

Motors will be connected only to the ESC, and the most common use of motors for this UAV is to spin the propellers of the UAV and to enable the UAV fly. UAV motors may also be found in other unmanned vehicle subsystems, such as camera and payload gimbals, flight surfaces, antenna rotators and landing gear. The selection of a UAVs motor for a particular drone propulsion system will depend on many factors, particularly the weight of the drone. A UAV motor needs to be able to generate enough thrust to contracts the weight of the UAV and enable it to achieve lift off [Fig 4].

Fig 4: The electric motor

Remote control

The remote control to be used has a wireless interface which enable the aircraft to be remotely controlled without actually being in contact with the UAV. Remote control is a device that a UAVs pilot holds in his or her hands that makes the UAV do what the pilot wants [Fig 5].

Fig 5: Remote control

RC Flight controller

The flight controller will be connecting the ESC, the autopilot and all the four servos used in the work will also be connected to it. The proposed receiver to be used in this research work is called a futaba flight controller and it has a receiver transmission Range of 12km distance [Fig 6]. The receiver model is, Corona - R8SF 8channel and 2.4 GHz-FHSs compatibility receiver, with the operating current of 60mA max, receiver wavelength will be 98dbm, and with the weight of 8 g. A flight controller, on the other hand, is the circuit board that translates information from the drone remote controller into action. A drone RC Flight controller works by sending a radio signal from the remote control to the drone, which tells the UAV what to do. Radio signals are sent from the radio transmitter in the UAV controller and received by the UAVs receiver. This is why the UAV flight controller is sometimes simply called the UAV radio transmitter or the UAV radio controller.

Fig 6: Futaba RC Flight controller

Autopilot for autonomous

The autopilot will be connected to the ESC and Rc Flight controller, the autopilot used in this research is called Matek with the autopilot model of Matek F405SE wings controller. UAV autopilot systems allow the aircraft to perform entire missions autonomously without the need for manual remote control. These missions may include cargo delivery, mapping, surveillance and many other applications. Operators use ground control stations to set the parameters of the mission and the UAV autopilot directs the drone or other unmanned craft to complete the task [Fig 7:].

Fig 7: UAV Autopilot

Electric servos

Electric Servos (aka actuators) are essential to the operation of most UAVs because they provide the ability to move control surfaces. In this research work, four electric servos were used, in which the four of them will be connected to the receiver and they have their respective names and function as follows;

Servo 1 This is called a Rudder. The rudder is a primary flight control surface which controls rotation about the vertical axis of an aircraft. This movement is referred to as "yaw". The rudder is a movable surface that is mounted on the trailing edge of the vertical stabilizer or fin.

Servo 2 This is called a Flaps. A flap is a high-lift device used to reduce the stalling speed of an aircraft wing at a given weight. This movement is referred as pitch motion. Flaps are usually mounted on the wing trailing edges of a fixed-wing aircraft. Flaps are used to reduce the take-off distance and the landing distance.

Servo 3 This is called a horizontal stabilizer. The horizontal stabilizer prevents up-and-down, or pitching, motion of the aircraft nose. Because the elevator moves, it varies the amount of force generated by the tail surface and is used to generate and control the pitching motion of the aircraft. There is an elevator attached to each side of the fuselage.

Servo 4 This is called a deflectable landing gear. The deflectable landing gear is the undercarriage of an aircraft and can be used for landing of the aircraft. It can also be called alighting gear.

3.0 Software (motorcalc)

The motorcalc software will be used to simulate the onboard electronic components of this research work.

Results

The Fig 8 shows the general parameters used in the simulation to obtained the results in Figures 9 and 10. The parameters were presented with their respective units.

Here we used motorcalc simulation software for complex calculation and graphs for motor characteristics and efficiency thrust limitation as shown in Figures 9 and 10.

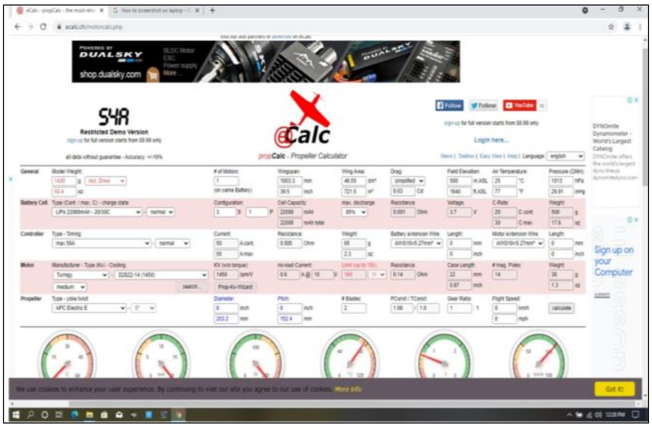

Fig 8: Parameters and units used for the simulation in motorcarlc software

Results from the simulation software (motorcalc) is shown in the figures below.

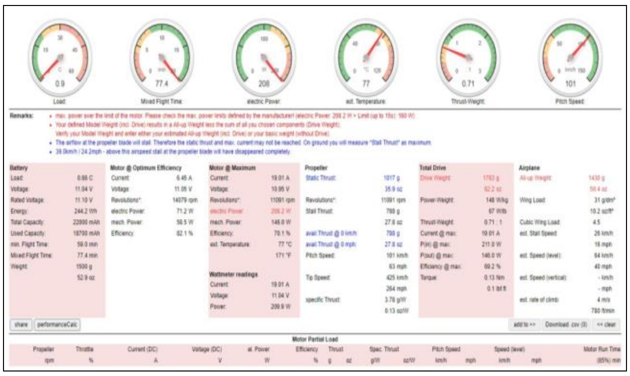

Fig 9: UAV Simulation Result

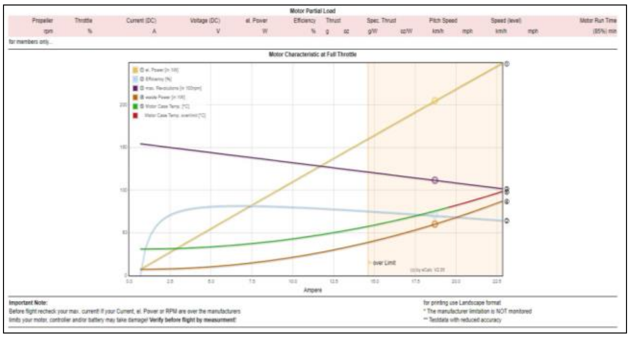

Fig 10: UAV Simulation Graph

Discussion

From the simulation software (motorcarlc) in figure 4.2 above, it was observed that, the lipo (lithium polymer) battery has a load, weight, energy, minimum flight time, maximum flight time, total capacity and used capacity of 0.8 C, 1500 g, 244.2 Wh, 59.0 minutes, 77.4 minutes, 22000 mAh, and 18700 mAh respectively.

Also, the motor at optimum efficiency generate current, voltage, Resolutions, electric power, mechanical power, and efficiency of 6.45 A, 11.05 V, 14079 rpm, 71.2 W, 58.5 W, and 82.1 % respectively.

Also, the motor at maximum efficiency generate current, voltage, Resolutions, electric power, mechanical power, efficiency and estimated temperature of 19.01A, 10.95V, 11091rpm, 208.2 W, 146.0 W, 70.1 % and 77 °C respectively.

Also, the propeller has a static thrust, resolution, stall thrust, avail thrust at 0km/h, pitch speed, tip speed, and specific thrust of 1017 g, 11091 rpm, 788 g, 27.8oz, 101 km/h, 425 km/h and 3.78 g/W respectively.

Also, the total drive was observed to have a drive weight, power weight, thrust-weight, maximum current, power in at maximum, power out at maximum, maximum efficiency and torque of 1763g, 148 W/kg, 0.71:1, 19.01 A, 211.0 W, 146.0 W, 69.2 %, and 0.13 Nm respectively.

And finally, the aircraft was observed to has a total weight, wing load, cubic wing load, estimated stall speed, estimated level speed, and estimated rate of 1430 g, 31 g/dm², 4.5, 26 km/h, 64 km/h, and 4.0 m/s respectively.

Also, from Fig 10 above the motor characteristics at full throttle was obtained. The results show that, the electrical power was proportional to the current in ampere.

And also, the efficiency increases above 50 % before it started dropping with respect to the ampere.

And the maximum resolutions vary inversely proportional to the ampere. And at initial the waste power forms a concave slope to the ampere, and above the initial the motor case temperature also formed a concave slope from 10A to 22.5A, which shows that both the waste power and motorcase temperature increased non-uniformly with respect to the increase in amperes. Thus, the UAV onboard electronics design coupled with the structural designed performed optimally according to the design mission of the aircraft.

Conclusion

This research work focuses on the conceptual, preliminary, and aerodynamic study for a fixed wing unmanned aerial vehicle, designed under flight conditions and a specific mission. In fact, the conceptual design was made under the specifications of the area covered by the solar cells, obtaining a minimum area that the vehicle must have for the solar cells; likewise, an estimation of the weight was obtained involving all the electronic and structural elements. The empennage and fuselage were designed based on aerodynamic calculations to obtain the best glide angle which will give a static stability in the glide time. In this sense, a comparison of different airfoils was performed considering the characteristics and parameters of our platform. A preliminary model was obtained based on the conceptual design, and an aerodynamic analysis was carried out by means of computational fluid dynamics to analyze the lifting force produced by the UAV. The simulation proved to be very useful for checking the design calculations that were made obtaining an aircraft capable of carrying out its flight mission. Power tests were carried out using the battery, its polymer-based coating which reduces the weight and can be applied to our platform.

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