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Design and Development of Flying Vehicle

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ABSTRACT: The objective of this project is to study and construct a motorized flying machine, namely Verticop. Like a bi-copter, it can fly with two blades of propeller. The flying vehicle is capable of flying with thrust force produced by its two propellers. The whole system of this flying vehicle is controlled by a wireless communication system using radio frequency. As a controller, Flight controller, KK2.1.5 is used for stabilization of this vehicle during the flight. The vehicle was able to fly very smoothly and stable under the controlled of the controller module. The stability of Verticop depends on the adjustment of gyroscope in the controller which controls the pitch, roll, and yaw in its orientation.

KEYWORDS: Propeller, Wireless Communication System, Flight Controller, gyroscope.

I.INTRODUCTION

Nowadays, Research and development of unmanned aerial vehicle (UAV) and micro aerial vehicle (MAV) becomes high popularity, because the application of UAV and MAV are effectively employed in dangerous situation. In the flying stage, the ability of taking vertical off is very important. The vehicle can take off and land vertically within the limited area. The operation range is limited based on the transmitter and receiver capacities of wireless controlled module. The operation of flying vehicle is efficient in dry condition of environment. Comparing to all other multi-copters, bi-copter has less lifting power and is less stable. The vehicle with two rotors requires a very robust electronic autopilot to maintain control of the vehicle. They can apply to variety of area such as rescue mission, military, film making, agriculture and others. [1]

II.LITRATURE REVIEW

Based on the principle of Tandem Rotors Helicopter, the Verticop works efficiently. In the structure of Tandem rotor helicopters, two large horizontal rotor assemblies is mounted one in front of the other. With each cancelling out the other's torque producing by propeller, Tandem rotor helicopters use counter-rotating rotors. Therefore all of the power from the engines can be used for lift (force), whereas a single rotor helicopter uses some of the engine power to counter the torque. The transmission of two rotors are linked to ensure that the rotors are synchronized and do not hit each other, even during an engine failure [1]. The yaw system of Tandem rotor designs can achieve by applying opposite left and right cyclic to each rotor, effectively pulling both ends of the helicopter in opposite directions. The pitch condition can achieve by applying the opposite collective to each rotor which is decreasing the lift produced at one end, while increasing lift at the opposite end. Controlling the pitch is effectively tilting the helicopter forward or back. Advantages of the tandem- rotor system are a larger center of gravity range and good longitudinal stability.

The constructed Verticop is controlled through Graphical User Interface (GUI). Because of communication between GUI, it can be controlled by using wireless communication system. The balanced condition of Verticop depends on the sensing effect of both sensors and gyros. Flight controller involving sensors and gyros is used to stabilize the vehicle during flight. Controller takes signals for roll, pitch and yaw from the on-board gyroscopes. It sends these signals to the processor, which in turn processes these signals. After receiving these signals, processor passes the control signals to the installed Electronic Speed Controllers (ESCs). Then, ESCs regulate the speed of the brushless DC motors to obtain stability of the vehicle [2].

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III. DESIGN OF VERTICOP

In the construction of Verticop, PVC pipe and Aluminum are taken as material. Aluminum is used for motor housing frame and PVC pipe is used for body which carries the microcontroller, battery and other electronic components.

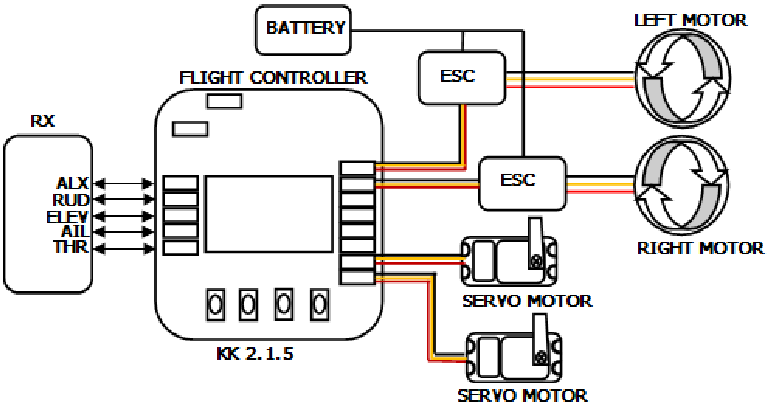

Figure 1.Block Diagram of Verticop

3.1 Motor Housing Frame

The motor housing frame design is important to match with the rotational speed of motor. The housing frame has two arms of length 231.3 mm from the centre of the body structure. To increase the strength of the structure, these are screwed to the central portion of the body. The weight of motor is distributed equally along the two arms for providing balance. The material of the Verticop is set to Aluminum and PVC pipe for better weight to power and strength ratio.

IV. HARDWARE COMPONENTS

4.1 KK2.1.5 Flight controller board

The KK 2.1.5 Multi-Rotor LCD Flight Control Board is device which is stabilizing unit for aerial vehicles. It consists of 8 motor layout pins to the right and 5 receiver outputs to the left. The transmitter - receiver channels and options are shown in figure 2. It consists of the LCD board displays outputs and allows calibration of ESCs, sensor modules such as the gyros and accelerometer. With the help of this module, the user can choose the controlled signal for a variety of motor layouts. The Proportional Integrator (PI) gain values can also be adjusted by pushing four buttons provided at the bottom. The convenience of the flier can get by adjusting the transmitter channels and the maximum and minimum values for each channel can also be set [3].

The task of Flight controller is to stabilize the flight. As a controlling, it takes signals from the gyroscopes and these signals are passed to the processor. After that the processor sends the particular control signals to the Electronic Speed Controllers (ESCs). According to the control signal, the ESCs provide fine adjustments the rotational speeds of motors which in-turn stabilizes the craft. The Hobby King KK 2.1.5 Multi-Rotor controller board can receive and transmit the required signals from the radio system via receiver (Rx). These signals together with stabilization signals are sent to the processor via the aileron; elevator; throttle and rudder as user demand inputs. Once it receives processing signal, this information is sent to the ESCs. After adjusting the rotational speed of each motor by ESCs, it controls flight orientation (up, down, backwards, forwards, left, right, yaw). KK2.1.5 multi rotor control board is shown in figure 2.

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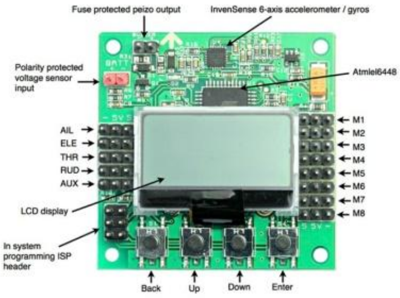

Figure 2.Controller board of kk2.1.5

4.3 Brushless DC motors

In the construction of flying machine, motor selection is a pivotal role to produce the required thrust force by the motor. The required force is responsible for vertical take-off and landing. Brushless DC electric motor is also known as electronically commutated motors or synchronous motors, which are powered by a DC electric source via an integrated inverter/switching power supply. Brushless DC motor is shown in figure 3.

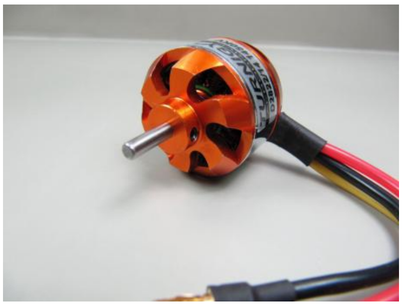

Figure 3.Brushless motor 1400kV

4.3 Electronic speed controller

An electronic speed control or ESC is an electronic circuit. The purpose of ESC module is to vary a motor's speed, rotor direction and also to act as a dynamic brake. ESCs are often used on electrically powered radio controlled model [3].

An electronic speed controller is a stand-alone unit employed to vary the speed of a motor. The ESC is powered by a battery and the DC signal from the battery is fed to the inverter circuit in the ESC. The resulting three output signals are given to the motor. The direction of rotation of the motor can be varied by interchanging any two output signals from the ESC. ESC receives input Pulse Width Modulated (PWM) signals ranging from 1000 – 2000 microseconds (μs). The pulse width 1000 corresponds to zero throttle and 2000 to full throttle.

Figure 4.ESC component

4.4 Servo motor

A Verticop exhibits three directional tendencies while in the air – roll, pitch and yaw. In order to control the motion, a servo gear is connected the motor mount. The bidirectional movement of the servo gear enables movement in either desired direction. The servo motor is mainly part of the orientation of vehicle which is able to produce enough torque to rotate the motor mount quickly. The size and weight of the servo motor also play an important role and are largely dependent on the Verticop servo frame allotments. The servo on the Verticop is located on the aft rotor and it is responsible for thrust vectoring the aft rotor for yaw control and the stabilization unbalanced torque. As an ESC's operation, servo motor receives a signal from the receiver through PWM exactly.

Figure 5.Servo motor

4.5 Lithium polymer battery

The battery plays a very significant role in the construction of an unmanned aerial vehicle. Flight endurance, agility, capability to hover and a host of other factors are determined by the capacity of the battery. A cell measures a nominal voltage of 3.7V. A 3cell battery inadvertently implies a voltage of $3*3.7V = 11.1V$ and hence most often expressed as "3 Cell" or "3 Li-Po" in case of Lithium Polymer. Most battery capacities are either expressed as mAh (milliamp/hr.) or Ah (Amp/hr.) to indicate the battery size. When speaking of batteries, discharge current is usually expressed as C-rate to normalize the measure against battery capacity. 1C literally means that the discharge current discharges the entire battery in one hour. To ensure longer flight time, higher batteries are chosen and thus the increase in weight [4].

Figure 6.Lithium polymer battery

4.6 Propeller

Propeller is also the main part of the vehicle flying for producing the required thrust force. There are two types of propellers used CW and CCW. CCW propellers are also called as normal propeller which is moving in counter clock wise direction and they are mounted to the motor. CW propellers are also called as pusher propellers and they are mounted to the motor which is moving in the clock wise direction [3].

Figure 7.Propeller

4.7 Radio Control module, transmitter and receiver

An RC Module (Radio Frequency Module) is known as electronic device which is used to transmit and/or receive radio signals on carried frequencies. Figure 8 shows RC transmitter and receiver used in vehicle. The transmitter and receiver occupy a very significant role in the control of any unmanned aerial vehicle. Typical receivers have 6 channels and the number of channel varies depending on the vehicle configuration and the flying style. The 6 channels of a receiver are Aileron, Elevator, Throttle and Battery, the rudder and AUX options [4].

Figure 8.Radio control, transmitter and receiver

V. OPERATION OF VERTICOP

The works of Verticop is based on the principle of Tandem Rotors Helicopter. Tandem rotor helicopters, uses counter-rotating rotors, with each cancelling out the other's torque. The overall lift force is provided by the power of engine. The configuration of two rotors is ensured to fix not to hit each other. The two rotors operate synchronously by the linking of their ensured transmission. The pitch system can be controlled by opposite processing of each rotor which means that the produced lift decreases at one end, while increases lift at the opposite end. The vehicle can move forward or back by changing pitch which is effectively tilting the angle.

Figure 9.Motor housing frame

Figure 10.Structure of Verticop

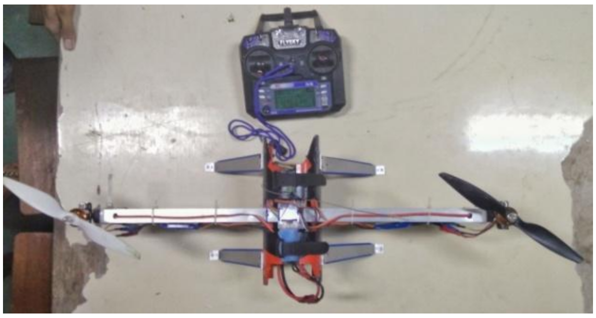

Figure 11.Top view of Verticop

The sensing signals of sensor and gyro are important for the balancing of the verticop. Flight controller is used for stabilization of the vehicle during flight in the air. For the stabilization of the vehicle, controller takes signals from the on-board gyroscopes for roll, pitch and yaw. These signals pass to the processor, and makes processing. After processing, the processor sends out the control signals to each ESC unit. After installing these commands, Electronic Speed Controllers (ESCs) regulates the particular speed of the DC motors to obtain stability of the vehicle.

VI. ANALYSIS ON VEHICLE

The acquired data are the thrust of the propeller set at a 4.5 degree pitch while the motors was idling around 1400 kV. The static, dynamic thrust data and the flight forward velocity for each thrust are calculated by using Drive calculation Software. The respective graphs and data are shown.

Here Drive calculation Software is used for complex calculation and graphs for propulsion system and efficiency. From the above calculations and analysis, we can say that the thrust produced by the two rotors is quite sufficient enough to lift the model.

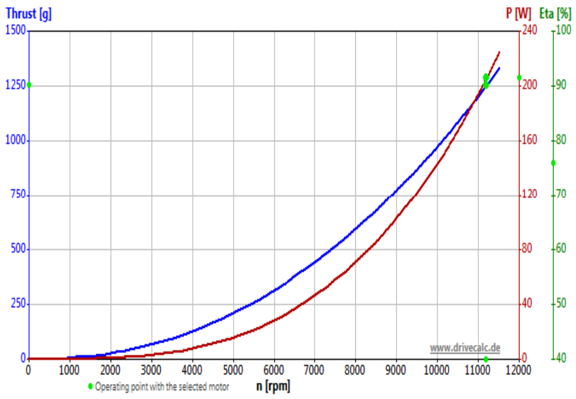

Figure 12.Thrust and Power vs. Prop's RPM

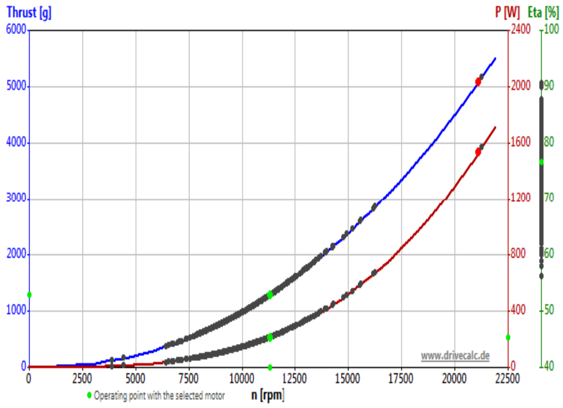

Figure 13.Thrust and Power vs. current

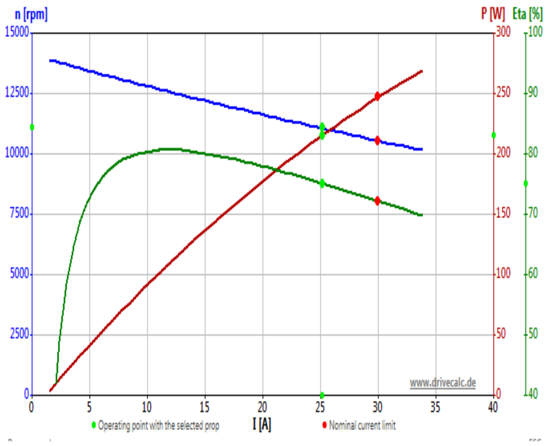

Figure 14.Prop RPM and Power vs. current

Figure 15.Propulsion system curve in flight analysis

VII. RESULTS AND DISCUSSION

This vehicle is fabricated using aluminum and PVC pipe as a frame. These are light in weight, and sufficient high the power to weight ratio. To get the required thrust force, the selection of the motor and propeller is taken into consider. After placing all the electronic components on its frame, the CG of verticop is required to adjust for balancing. If it is not balanced, the vehicle may not move properly in the right direction and it causes unstable during the flight. The battery is placed at the centre of the body to distribute weight equally on both the sides. Then the Verticop is tested for its vertical takeoff, forward and backward movements. With the increasing of throttle in the transmitter, the Verticop lifts up when the thrust equals its weight. Getting increase in the throttle, the Verticop fly's high. The microcontroller consists of built-in sensors and it senses any deviation in the flight. The sensors detect deviation error and the detected error deviation data is input to the processor which processes it. Processor sends control signals to the speed controllers via ESCs to stabilize the flight. In the self-level settings for ideal flight, the Verticop is tested multiple times by changing the roll axis trim and pitch axis trim values. The Verticop moves in the forward and backward directions by increasing the speed of the respective motors.

VIII. CONCLUSION

For the Verticop design, the main considerations are to lift the required payload, to achieve a desired speed, and maintain stability. Using a larger propeller provides generating more thrust, with larger arms on the frame. The higher the moments of inertia, the more the stability can get. The lower kV motor gives the higher torque to spin the larger propeller. The vehicle, Verticop, was able to fly very smoothly and stable.

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