

Vertical Takeoff and Landing (VTOL) aircraft using Tiltrotor Mechanism

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Abstract— A multi rotor is aircraft which generates lift and propulsion by way of one or more powered rotors mounted on rotating engine pods usually at the ends of a fixed wing which drive the shafts transferring power to rotor assemblies mounted on the wingtips. It combines the vertical lift capability of a helicopter with the speed and range of a conventional fixed wing aircraft. For vertical flight, the rotors are angled so the plane of rotation is horizontal, lifting the way a helicopter rotor does. As the aircraft gains speed, the rotors are progressively tilted forward, with the plane of rotation eventually becoming vertical. In this mode the wing provides the lift, and the rotor provides thrust as a propeller.

Keywords- Multi rotor, Aircraft, Helicopter, vertical, thrust.

I. INTRODUCTION

A vertical take-off and landing (VTOL) aircraft is one that can hover, take off, and land vertically. This classification includes fixed-wing aircraft as well as helicopters and other aircraft with powered rotors, such as cyclogyros/cyclocopters and tiltrotors. Some VTOL aircraft can operate in other modes as well, such as CTOL (conventional take-off and landing), STOL (short take-off and landing), and/or STOVL (short take-off and vertical landing). Others, such as some helicopters, can only operate by VTOL, due to the aircraft lacking landing gear that can handle horizontal motion. VTOL is a subset of V/STOL (vertical and/or short take-off and landing). Besides the ubiquitous helicopter, there are currently two types of VTOL aircraft in military service, craft using a tiltrotor, such as the Bell Boeing V-22 Osprey, and another using directed jet thrust, such as the Harrier family and new F-35B Lightning II Joint strike Fighter (JSF). Generally speaking, VTOL aircraft capable of STOVL use it wherever possible, since it typically significantly increases take-off weight, range or payload compared to pure VTOL. A tiltrotor is an aircraft which generates lift and propulsion by way of one or more powered rotors (sometimes called proprotors) mounted on rotating engine pods or nacelles usually at the ends of a fixed wing or an engine mounted in the fuselage with drive shafts transferring power to rotor assemblies mounted on the wingtips. It combines the vertical lift capability of a helicopter with the speed and range of a conventional fixed-wing aircraft. For vertical flight, the rotors are angled so the plane of rotation is horizontal, lifting the way a helicopter rotor does. As the aircraft gains speed, the rotors are progressively tilted forward, with the plane of rotation eventually becoming vertical. A tiltrotor aircraft differs from a tiltwing in that only the rotor pivots rather than the entire wing. This method trades off efficiency in vertical flight for efficiency in STOL/STOVL operations.

II. DESIGN

There are several thumb rules in aero modelling to design a multirotor and a plane. For a multirotor the distance between the motors should be 1 and half propeller length (depends on propeller used). To build a canard plane the aspect ratio of the wings should be approximately 3:4. But these are for ideal

condition, suitable changes are made to adopt both concepts in the same model. To meet these design requirements the following materials are used.

MATERIAL SELECTION

The following materials are used in building the multirotor:

A. Pine Wood



Figure 1: Pine Wood

Pine is softwood which grows in most areas of the Northern Hemisphere. There are more than 100 species worldwide. Properties: Pine is a soft, white or pale yellow wood which is light weight and straight grained.

B. Aluminium



Figure 2: Aluminium L Clamp

Aluminium is remarkable for the metal's low density and its ability to resist corrosion through the phenomenon of passivation. Aluminium and its alloys are vital to the aerospace industry and important in transportation and structures, such as building facades and window frames. The oxides and sulphates are the most useful compounds of aluminium.

Despite its prevalence in the environment, no known form of life uses aluminium salts metabolically, but aluminium is well tolerated by plants and animals. Because of their abundance, the potential for a biological role is of continuing interest and studies continues.

C. SS Wires, Nuts and Bolts



Figure 3: SS Wires, Nuts & Bolts

Stainless steels are often selected for their corrosion resistance, but they are often also construction materials. Mechanical properties such as strength, high temperature strength, ductility and toughness are also important considerations. Stainless steel wire does not rust and is durable and strong. Due to its various sizes and lengths, it has many uses in and around the house. For the outdoors, it can be implemented in agriculture, marine applications and architecture.

D. Airfoil

The aerodynamic characteristics of NACA 0012 measured in a low-speed wind tunnel at Reynolds numbers up to 2.88×10^6 are presented, and it is hoped that they are free from substantial error or uncertainty despite two major difficulties that were encountered in the neighbourhood of the stall. The possibility that the stall might be prematurely initiated by the onset of flow separation in the corners between the wing and the tunnel walls had led to the provision of a form of boundary-layer control. Whilst the use of this device eliminated a very obvious departure from two-dimensional conditions, the use of excessive boundary-layer-control flow quantities making the stall less likely to start in the corners, rather than more so, was equally unsatisfactory in that it introduced a different mode of three-dimensionality into the

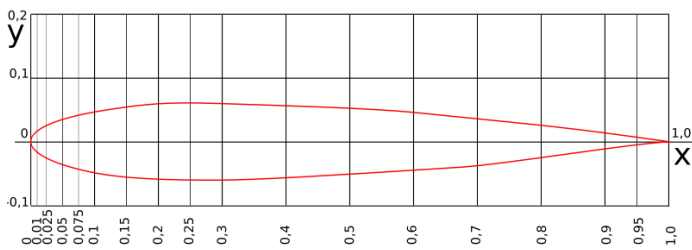


Figure 4 : NACA air profile

test conditions, namely, a wave in the turbulent separation front. Despite endeavors to avoid this situation it was found that gross three-dimension- ability (designated a stall cell) was present in post-stall conditions, and there is a little evidence which suggests that it develops just prior to the stall, and that it is not particularly associated with the application of boundary-layer control. If the three-dimensionality spreads to any great extent it may altogether prevent true CL max from being measured, since in the presence of induced-flow conditions, the line of pressure holes may not lie along a streamline or in a region of two-dimensional flow, and the local incidence may jump from a pre-stall incidence to a post-stall incidence as geometric incidence is gradually raised. Such behavior does not nullify the use of two-dimensional data in lifting-line type calculations, but merely rendered the determination of data impossible in this particular experiment. Further attempts to obtain two-dimensional flow conditions through the stall, and to assess quantitatively the extent of three-dimensional flow otherwise encountered.

E. Foam

Foam core or Foam board is a lightweight, and easily cut material used for the mounting of photographic prints as backing in picture framing, in 3D design, and in painting. It is also in a material category referred to as "Paper-faced Foam Board". It consists of three layers – an inner layer of polystyrene foam clad with outer facing of either a white clay coated paper or brown craft paper.



Figure 5 : Foam

F. Design of four bar Mechanism

A four-bar linkage, also called a four-bar, is the simplest movable closed chain linkage. It consists of four bodies, called bars or links, connected in a loop by four joints. Generally, the joints are configured so the links move in parallel planes, and the assembly is called a planar four-bar linkage. If the linkage has four hinged joints with axes angled to intersect in a single point, then the links move on concentric spheres and the assembly is called a spherical four-bar linkage. Bennett's linkage is a spatial four-bar linkage with hinged joints that have their axes angled in a particular way that makes the system movable.



Figure 6 : Parallelogram four bar Mechanism

then the shortest link can rotate fully with respect to a neighboring link. In other word, the condition is satisfied if $S+L \leq P+Q$ where S is the shortest link, L is the longest, and P and Q are the other links. As the crank rotates 1deg rocker will also rotate 1deg hence the angle rotated by rocker is same as that of crank.

The Grashoff condition for a four-bar linkage states: If the sum of the shortest and longest link of a planar quadrilateral linkage is less than or equal to the sum of the remaining two links,

III. ELECTRONICS USED

A. Motor

Brushless motors may be described as stepper motors however the term "stepper motor" tends to be used for motors that are designed specifically to be operated in a mode where they are frequently stopped with the rotor in a defined angular position. Motor of Prop 1145 has been selected, where 11 inch prop, 4.5 inch pitch was suitable.



Figure 7 :Sunysky X2212

B. Propellers

A propeller is a type of fan that transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces of the air foil-shaped blade, and a fluid (such as air or water) is accelerated behind the blade. Propeller dynamics, like those of aircraft wings, can be modelled by either or both Bernoulli's principle and Newton's third law. A



Figure 8 : Propellers

marine propeller of this type is sometimes colloquially known as a screw propeller or screw, however there is a different class of propellers known as cycloid propellers - they are characterized by the higher propulsive efficiency averaging 0.72 compared to the screw propellers average of 0.6 and the ability to throw thrust in any direction at any time.

C. ESC

Most modern ESC contains a microcontroller interpreting the input signal and appropriately controlling the motor using a built-in program, or firmware. In some cases it is possible to change the factory built-in firmware for an alternate, publicly available, open source firmware. This is done generally to adapt the ESC to a particular application. Some ESCs are factory built with the capability of user upgradable firmware. Others require soldering to connect a programmer.



Figure 10 : ESC

D. KK2 Microcontroller

The original KK gyro system has been updated to an incredibly sensitive 6050 MPU system making this the most stable KK board ever and allowing for the addition of an auto-level function. At the heart of the KK2.1.5 is an Atmel Mega644PA 8-bit AVR RISC-based microcontroller with 64k of memory. An additional polarity protected header has been added for voltage detection, so no need for on-board soldering. A handy piezo buzzer is also included for audio warning when activating and deactivating the board.



Figure 11 : KK2 Microcontroller

The KK2.1.5 added polarity protection to the voltage sense header and a fuse protected buzzer outputs, in case something is accidentally plugged in incorrectly. The voltage sense line has been updated for better accuracy. The board is clearly labelled and the voltage sense line color has been changed to red for easy identification, making installation and connections a snap.

E. BEC & Battery

It's used when ESC doesn't have built-in BEC, or standalone power system is required for flight controller, radio receiver or servos. They generally are more efficient, more reliable and able to provide more current than BEC. The UBEC is connected directly to the main



Figure 12 : BEC

battery of the quad copter, the same way as the ESC.



Figure 13 : 2800 mAh Battery

IV. RESULTS AND DISCUSSIONS

Various test flights were conducted which revealed various problems which has been tackled and the end product is built rectifying these problems.

A. Prototype 1



Figure 9 : First prototype model

The tilt has a lot of play which was evident at the time of flight which makes it very difficult to synchronize the motor rotation. We encountered another problem where the frame of the multicopter started flexing or wrapping which is a result of less rigid frame .this wrapping makes the aircraft unstable in flight.

B. Prototype 2

Rectified the earlier problems by using a wooden frame which improves the rigidity but the linkages in the tilt mechanism have greater degree of play which makes it more difficult to stabilize the aircraft.



Figure 14 : Second prototype model

The play produced by tilt mechanism is reduced than the previous prototype but not to a greater extent.

C. Final Prototype

There is no play between the servo arm and motor mount (completely synchronized) the weight of the aircraft is 1200 grams which has a power to weight ratio of 4:1.



Figure 15 : Final prototype model

There is no flexing of the frame which makes it highly rigid. The change of tilt mechanism and the change of frame reduces the total play in the system so that the desire stability of the aircraft is achieved.

V. CONCLUSIONS

The overall objective of the project was to design and develop an autonomous unmanned aerial vehicle. The model was tested with a fair breeze which was around 5-7kmph. For precautionary measures the aircraft was not allowed to go more than 10 feet of the ground.

- It achieved a height of 6.5 feet at less than 15% throttle. This provides sufficient evidence about the optimum power to weight ratio imparting good payload capability (about 900g payload capacities). The flight characteristics were positive even as the

conditions were windy and found it to have very quick response time, high level of stability even on that brisk day. At full throttle it could approximately achieve a height of 100-150 feet.

- The tilt mechanism is suitably synchronized so that the throw of the servo is accurately equal to the rotation of the motor mount. Adjustments of servos were made so that the motors are accurately synchronized with each other. There is a provision so that tilting of the motors can be achieved individually. This also increases the manoeuvrability of the aircraft.
- The stability of the aircraft is good and the gyros needed a little trimming which is done. The controls of aircraft are proportional and the time response of the aircraft is quite good.
- The approximate flight time has been calculated is around 6 minutes at full throttle. The flight time on the test day was 2min 10sec with 85% of the battery left (not on full throttle).

This proves for a fact that “Vertical Takeoff And Landing(VTOL) Aircraft Using Tilt Rotor Mechanism” can fly with good stability in multirotor mode as well as when the rotors are tilted, which profoundly increases manoeuvrability than the previous designs of multirotors.

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