Design and Fabrication of a Remote Controlled Vertical Take-off and Landing aircraft

Kalbende S. J.,Muttepwar V.V.,Wagaskar K. B.,Gawade K. G., Guided by Prof.Lakal N. V.

Abstract—**With the advancement of technology in each and every sector; aviation has always played a key role in innovations and new designs. One such type of aircraft initially designed for military purpose was VTOL i.e. Vertical Take-off and Landing. After taking off vertically while switching to forward motion, VTOL aircraft may face accident due to insufficient lift. At the time of conventional landing propellers may hit ground causing damage to propellers and it may crash. To overcome these problems, a new concept is proposed as Vertical take-off and landing. Vertical take-off and landing is a tilt rotor aircraft, having contra rotating co-axial motors driving the propellers. The contra rotating co-axial motor arrangement is done to get more lift than conventional thrust vectoring mechanism with the help of pull push action. The push pull action generates maximum lift during take-off. Two servo motors are used to drive thrust vectoring mechanism from vertical to forward direction and vice versa. Design of model is done in CATIA. Model is fabricated by using light weight HDT. To increase the flight time, wing span of an aircraft is as increased to make it glide in case of low propeller thrust. Practical testing shows that it overcomes the problem of insufficient lift.**

*Index Terms:***VTOL, Co-axial motors, Vertical take-off and landing, Tilt rotor aircraft, Thrust vectoring mechanism.**

I. INTRODUCTION

Aerodynamics is the study of forces and motion of objects through the air. With the development of countries and the race to be best in every sector made army, navy and air-force important. As a fastest mode of transport aircraft has been given a prime importance. As for every aircraft it is not possible to have a proper runway for landing at each and every condition leads to the development in vertical take-off and landing (VTOL) concept.

Vertical Take-Off and Landing (VTOL) aircrafts are able to take-off with the agility of a helicopter and can fly like an aircraft. These aircrafts have ability to land as conventional one. By definition, these aircrafts must be able to take-off vertically and transition into conventional flight and be able to return to hover mode for landing.

Manuscript received May 09, 2014.

SagarJayprakashKalbende, Department of Mechanical Engineering, Sinhgad Institute of Technology, Lonavala.

VenkateshVishnuraoMuttepwar, Department of Mechanical Engineering, Sinhgad Institute of Technology, Lonavala.

KiranBhaskarWagaskar, Department of Mechanical Engineering, Sinhgad Institute of Technology, Lonavala.

KetanGulabGawade, Department of Mechanical Engineering, Sinhgad Institute of Technology, Lonavala.

Prof N. V. Lakal,Department of Mechanical Engineering, Sinhgad Institute of Technology, Lonavala.

For taking-off and landing, the aircraft's two wingtip mounted engine arms are tilted upward, so that the rotors function like a helicopter's rotor blades. For forward flight, the nacelles are rotated 90 degrees forward, so that the rotors function like an airplane's propellers. For a VTOL aircraft, the engines and wings are located relative to each other such that the engine outlet nozzles, which pivot downwardly to provide lift and are minimally covered by the wings, if at all. The wings may include lifting fans to supplement lift and provide pitch and roll control.

A remote controlled (R/C) planes ranges from small to large models made up from a variety of materials such as balsa wood, carbon fiber and high density thermocol (HDT). These R/C planes don't need engines to keep them flying; they are equipped with electric motors or gas engines to rotate propellers so as to reach desired altitude. An aircraft consist of one, two or four engines. These engines are basically gas turbine engines which work on varying area flow concept. An aircraft which take-off and land vertically mainly has various types of engines such as turboprop, turbojet, and turbofan. In earlier phase of VTOL, planes having IC engines were used such as X-41. The turboprop engine is used in case of V-22 Osprey and turbojet in case of F-35.

In commercial aircrafts these engines are generally located below the wings so that proper airflow can be maintained. In VTOL these engines are located either centrally or at the tip of a wing.

II. THEORY OF FLIGHT CONTROL

In flight, the aircraft rotates about its center of gravity, but the direction of the weight force always remains towards the center of the earth.

Lift is the force generated in order to overcome the weight which makes the aircraft fly. This force is obtained by the motion of the aircraft through the air. Drag is the Aerodynamic force that opposes the aircraft's motion through the air. Drag is generated by every part of the aircraft. Thrust is the force generated in order to overcome the drag which makes the aircraft fly in forward direction.

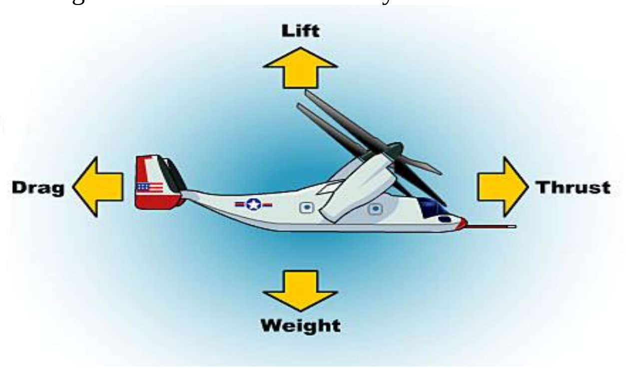

Fig. 1 Forces in Flight

During flight there are total six degrees of freedom. Vertical take-off and landing model that we developed has vertical, longitudinal, rolling and pitching motion. So it is a 3 channel R/C model.

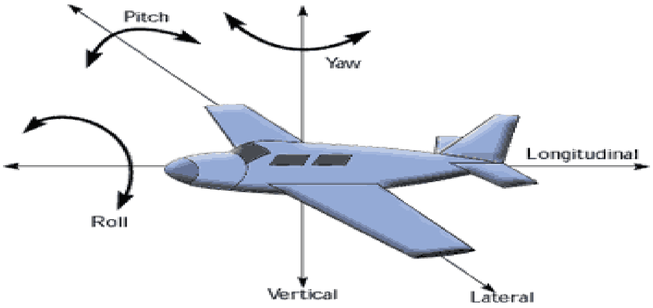

Fig. 2Degrees of Freedom

Ailerons: Located on trailing edge (rear) of the wing, the ailerons control the airplane's roll about its longitudinal axis. Each aileron moves at the same time but in opposite directions i.e. when the left aileron moves up, the right aileron moves down and vice versa. This movement causes a slight decrease in lift on the wing tip with the upward moving aileron, while the opposite wing tip experiences a slight increase in lift. Because of this subtle change in lift, the airplane is forced to roll in the appropriate direction i.e. when the pilot moves the stick left aileron will rise and the airplane will roll left in response to the change in lift on each wing. The ailerons are controlled by a left/right movement of control stick, or 'yoke'.

Elevators: The elevators are located on the rear half of the tail plane, or horizontal stabilizer. Like the ailerons, they cause a subtle change in lift when movement is applied which raises or lowers the tail surface accordingly in addition, air hitting deflected elevators does so in the same way as it hits the rudder i.e. with exaggerated effect that forces the airplane to tilt upwards or downwards. Moving the elevator up (pulling back on the yoke) will cause the airplane to pitch the nose down and dive. Elevators are linked directly to each other, so work in unison unlike ailerons

III. Design and Development of Model

The basic design of a model with proper dimensions is done in CATIA. It gives the view of a model to start fabrication.

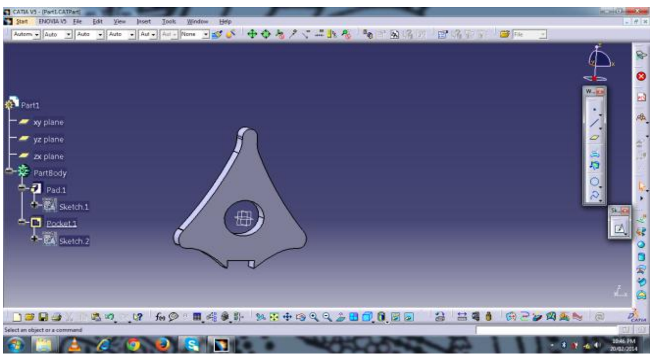

Fig. 3CATIA Model

The basic component selection and their weight calculation helps to calculate the thrust require during vertical take-off and during hovering.

Component Selection:

High Density Thermocol, Batteries, Brushless motors, Electronic speed controller, Servo motors, Propellers, Receiver and transmitter.

Component selection is depending on specifications of other components. For proper thrust and lift production synchronization of all components is necessary.

Thrust Calculations:

As per the theory during vertical take-off, thrust required should be 1.25 times that of weight of body. This required thrust depends on motors and battery voltage supply

S. No	Component	Approximate weight (kg)
1	Body (HDT)	0.5
2	Batteries	0.3*2 = 0.6
3	motors	0.2*2 = 0.4
4	Electronic speed controller	0.035*2 = 0.07
5	Servo motors	0.1 *2 = 0.2
6	Propellers	0.025*2 = 0.05
7	Skidders	0.1
	Total	**2.12**

Calculations:

Thrust calculation during vertical take-off

Thrust = 1.25 × weight of a model

= 1.25 × 2.12

= 2.65 kg.

Thrust calculation during hovering

Thrust = weight of a model

= 2.12 kg

Development of model:

There are two high density thermocol sheets with dimensions 6 mm and 3 mm which were used for making of base and upper portion of model respectively. Araldite klear is used as glue to give strength to model. Wingspan of model is 113 cm and nose to tail distance is 101 cm. Elliptical shape of minor diameter 33 cm and major diameter of 38 cm is cut through center of base for mounting of cowling. Cowling is a protective covering for propellers and for safety of user. It is usually made up of metal or plastic. As plastic is lightweight material so we select it for construction of cowling. Cowling of airfoil shape is cut having dimensions 5mm and 3mm at leading edge and trailing edge respectively. It is drilled diametrically and two bearings of inner diameter 5mm are fit into it. Carbon fiber rod having outer diameter 5mm is inserted into two bearings. These bearings are used to sustain load and to prevent bending of carbon fiber rod. Bearings also allow the mounting to rotate without any vibration. Diameter of cowling is decreasing from top to bottom so it will act as air duct. It allows air to flow downward at high pressure due to duct effect. By use of 10 mm thermocol sheet having 3mm width, ribs are cut precisely of airfoil shape. Ribs are glued along the length of wings which provide rigidity and strength to plane.

Balsa wood is cut as per given dimensions. It is sandwiched with two thin balsa wood plates to increase its strength. It is drilled with 5 mm diameter at center of smaller face. Carbon fiber rod of 5mm diameter is fixed in it. Four holes are drilled on larger face of balsa wood. Motors are mounted on these holes axially on opposite faces. Rotation of upper motor is counterclockwise and lower one is clockwise which creates puller-pusher action. A carbon fiber rod is passed through two bearings fixed in cowling which sustain the weight and stress of motor assembly. But at outer side of cowling rod act as a cantilever beam and may cause deflection due to its own weight. And this deflection results in improper working of motor assembly. So two wooden blocks are taken and bearings are fitted in them. Then the rod is passed through the bearing on both sides. These wooden blocks fixed on a model symmetrically such that it gives stability to rod.

For the rotation motor assembly orthogonally to convert motion from vertical to forward and vice versa, rotation of a rod has to be done by servo motor only. Initially we thought to drill the rod to connect servo .So the wooden block if fixed in rod. By using spoke clevises and aileron horns the rod is connected to servo arm. The rotation of servo arm result in rotation of rod orthogonally.

IV. WORKING OF MODEL

Two motors are mounted back to back coaxially, forming counter rotating motors mechanism. These counter rotating motors assembly mounted on rod are connected to batteries having electronic speed controller connected to them for controlling speed. Back to back mounting of motors, form puller-pusher mechanism for propellers. In this mechanism air is pull by upward propeller rotating in clockwise direction and downward propeller pushes air down which is rotating in counter-clockwise direction, creates the lift. After switching on remote controller, throttle is provided due to which propellers start rotating. After acquiring a certain speed, the thrust is generated due to which an aircraft takes off vertically. During a vertical motion, when an aircraft is reached to a desired altitude, the rod having counter rotating motor assembly mounted on it,is rotated orthogonally forming a forward motion mechanism. Rotation of rod is done by servo motors connected to it. A piece of thermocol, which is stick to the inner side of cowling, reduced drag and creates the aerodynamic airflow. An aerodynamic shape of a body helps to move an aircraft in forward direction.

V. CONCLUSION

The project design and modeling of a remote controlled motored vertical take-off and landing aircraft with axially mounted counter-rotating motors has more advantages compare to its disadvantages. This vertical take-off and landing aircraft does not need any run way for take-off and landing. Due to its large wing span area it has low speed gliding capability. It is very stable like co-axial helicopter. It is as fast as turbo propelled aircraft. It has very high cruise speed same as turboprop.

It has drawbacks such as it requires large amount of thrust, therefore being an issue to carry heavier loads. Higher trust needing more complex equipment and therefore the cost of the whole process increases substantially.

However in an era which needs faster modes of transport vertical take-off and landing is the future of aviation. In naval ships deck area is very limited so vertical take-off and landing is the solution to this problem which has high speed, long distance covering capacity, high load carrying capacity and stable flight. So it is also useful for army and air force. For cities which are getting densely populated and have no room for big airports, vertical take-off and landing serves as the best substitute. Also lowering the number of control surfaces eases the part of flying along with reduced cost and size of the aircraft.

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SagarJayprakashKalbende is a student of Department of Mechanical Engineering, Sinhgad Institute of Technology, Lonavala affiliated to Pune University. He is a final year student of Mechanical Engineering. He is currently working on design and fabrication of a remote controlled vertical take-off and landing aircraft.

VenkateshVishnuraoMuttepwar is a student of Department of Mechanical Engineering, Sinhgad Institute of Technology, Lonavala affiliated to Pune University. He is a final year student of Mechanical Engineering. He is currently working on design and fabrication of a remote controlled vertical take-off and landing aircraft.

KiranBhaskarWagaskar is a student of Department of Mechanical Engineering, Sinhgad Institute of Technology, Lonavala affiliated to Pune University. He is a final year student of Mechanical Engineering. He is currently working on design and fabrication of a remote controlled vertical take-off and landing aircraft.

KetanGulabGawade is a student of Department of Mechanical Engineering, Sinhgad Institute of Technology, Lonavala affiliated to Pune University. He is a final year student of Mechanical Engineering. He is currently working on design and fabrication of a remote controlled vertical take-off and landing aircraft.

He is an Assistant Professor in Mechanical Engineering department, SIT Lonavala. He has completed BE production, ME Mechanical Production and currently pursuing PhD. He is having total 11 years of teaching experience.