The International Journal Of Engineering And Science (IJES)
||Volume|| 3 ||Issue|| 01 || Pages || 48-52 || 2014 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

AERODYNAMIC DESIGNING OF AUTOGYRO: GYROCAME

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ABSTRACT

To design a compound architecture of a surveillance autogyro, combined with the short Takeoff and Landing STOL and efficient autorotation, free from rotor blades cyclic retrieval striking, vibration free features of gyroplanes. It comprises counter rotating transverse twin rotors mounted on the dihedral wing support, which is placed on top of the fuselage symmetrically, to produce the desired lift. The rotor blades are attached to the shaft at a constant pitch angle which operates efficiently during cruise flight. A tractor type configuration prop-rotor is used in order to propel the auto gyro at an efficient forward speed. The tractor prop-rotor is powered by means of a brushless motor. The general disadvantage of auto gyro (large drag) is overcome in our Gyrocame by increasing the wing span and reducing the length of the transverse rotor blades.

Keywords *- rotor blades, disc area, pitch angle, drag.*

Date of Submission: 24 December 2013 ⟷ Date of Acceptance: 10 January 2014

I. INTRODUCTION

An autogyro is an aircraft, similar to a modern helicopter in appearance, but with a few major dissimilarities. The design had inherent safety, better low-speed flight than airplanes, as well as the capability of vertical take-off and landing. One important feature of autogyro is its ability to flare, when there is a failure in engine, without causing much damage to the pilot and the rotorcraft. It, like a helicopter, uses an overhead rotor as its main source of lift. The rotor on an autogyro, however, is freely rotating, meaning it is not powered by any engine, and therefore applies no rotational force, or torque, on the machine. Because of the fact that the rotor does not spin on its own to give itself thrust like a helicopter, it makes for the need of another form of forward propulsion. This comes in the form of a propeller, like that on an airplane, to propel the machine forward, which makes air to pass though the overhead rotor, causing it to spin and create lift. The faster the machine goes the more lift the rotor creates.

Gyrocame is made out of chloroplast in order to reduce the weight and for crash resistance. Conventional type of fuselage construction is used along with a bicycle undercarriage. Front end of the fuselage consist of battery, receiver, electronic split controller and a brushless motor attached to the nose. A propeller with a fixed pitch angle is mounted on the shaft of the brushless motor. This propeller helps the rotorcraft in obtaining the required forward speed. The counter rotating twin rotors which produce the desired lift due to autorotation is attached to the fuselage using wing dihedral support. A flat bottom airfoil is used in the wing in order to acquire a high amount of lift at a short interval of time. The rotor consists of four blades, each placed at a constant pitch angle. The yaw and pitch movement are controlled by the rudder and elevator respectively which is attached to two separate servos. T type tail plane configuration is used in the low altitude rotorcraft.

II. LITERATURE SURVEY

Holger Duda [1] presented the flight performance of modern lightweight Gyroplanes which tends to increase the airspeed and the performance of gyroplanes by means of reducing the drag. H. Glauert [2] obtained a high lift forces from a freely rotating blades and the theory behind the lift generation. The maximum lift generation by using a proper disc area and the forward speed in general and studied the best lift-drag ratio. John W. Hicks [3] shows the lift and drag characteristics determined or met with respect to the drag polar shapes in subsonic speed for a various angle of attacks and for flight envelope. Seppo Laine [4] presented a work to study the importance of the horizontal tail on the longitudinal stability in horizontal flight. The study shows that the tailplane is necessary to ensure longitudinal stability. Woon-Tahk Sung [5] presented an integral and derivative based controller design method to achieve the desired performances of stability margin under parameter variations, demonstrating the usefulness of the proposed design scheme.

III. DESIGN AND FARICATION OF COMPONENT

3.1. Wing Support and Rotor Blades

Generally in autogyro the wing is been replaced by the use of support. The support is used for fixing the rotor blades. These rotor blades are mainly used for producing the lift. Here the support is inclined to a particular angle, so called dihedral angle which is of approximately 2 degrees. To calculate the dihedral angle we consider the planes for which the angles should be calculated. The general equation of the plane is given by:

$$Ax + By + Cz = 0$$

Comparing the two equation of plane and substituting in the below equation we get the dihedral angle

$$cos\alpha = \frac{A_1A_2 + B_1B_2 + C_1C_2}{\sqrt{A_1^2 + B_1^2 + C_1^2}\sqrt{A_2^2 + B_2^2 + C_2^2}}$$

Chloroplast sheet is used for making the support. Care should be taken that, too much of dihedral leads to unpleasant experience, or in extreme conditions it can lead to loss of control or can overstress an aircraft. The rotors are made such that it has 4 blades and are joined together with a small rectangular cardboard plate. The rotor blades are fixed with the small triangular support to the wing at a small pitch angle. The two rotors are kept or fixed at a particular distance to avoid turbulence and collision. The corners of the wing and rotor are covered with strips of balsa wood.

Unlike a helicopter, the rotor on an autogyro is not powered directly.As the machine moves forward in level flight powered by a propeller the resultant aerodynamic forces on the blades cause the necessary torque to spin the rotor and create lift. This phenomenon of "self-rotation" of the rotor is called autorotation.

A twin rotor blade is installed in the two sides of the support; four blades are attached together with the help of the center boss. An angle of 90 degree is maintained between the blades in order to produce lift. The rotation of blades are made in such a way that both the rotors rotate in opposite direction to each other.

The rotor blades are made with chloroplast for the reason of light weight and rigidity. The center boss is located at the distance of 29cm from the ends of the rotor blades. The length of the blades is 35cm and width 5cm with 60^o angle between the blades. The rotor diameter is 4mm with the rotor shaft weight to be 140g. The rotor blades are kept at the ends of the wings. A square sheet of cardboard is used underneath the rotors so that it reduces the friction created between the support and the blades. The blade is attached to the shaft at a small positive angle of pitch θ as shown in Fig.2.1.1 and Fig.2.1.2.

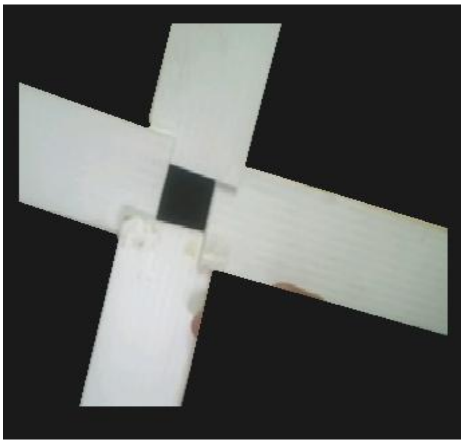

Fig.3.1.1 Blades construction showing the pitch angle

Fig.3.1.2Rotor blades construction

The airfoil in many aspects is the heart of the airplane. The choice of airfoil selection on a rotating wing aircraft is never an easy one because of the diverse range of Reynolds number and Mach number found along the length of the blades. The lift produced in autogyro is directly proportional to the forward speed. Since autogyro is a low speed flying aircraft, the lift generated is also proportionally reduced. In order to improve the lift production, a flat bottom airfoil is chosen for the wing support. Considering the above conditions Clark Y airfoil section as shown in Fig.2.1.3 is used.

The airfoil has a thickness of 11.7 percent and is flat on the lower surface from 30 percent of chord back as shown in Fig.2.1.4. The flat bottom simplifies angle measurements on propellers, and makes for easy construction of wings on a flat surface.

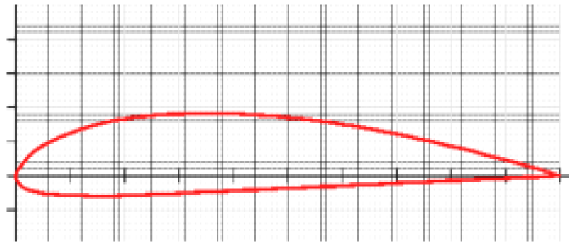

Fig.3.1.3ClarkYairfoil

Fig.3.1.4Airfoil section

3.2. Fuselage

The fuselage, or body of the autogyro, is a long hollow tube which holds all the pieces of an autogyro together. The fuselage is hollow to reduce weight. As with most other parts of the airplane, the shape of the fuselage is normally determined by the mission of the aircraft. The weight of an aircraft is distributed all along the aircraft. The centre of gravity of the autogyro is usually located inside the fuselage. The shape and dimensions of the fuselage have a strong effect on the aircraft drag.

Conventional type of landing gear is attached at the bottom of the fuselage. The fuselage includes covers enabling quick and easy access to components in the fuselage.3 servos are used and fixed in the fuselage body (1-elevator, 1-rudder & 1-throttle). Fuselage is of 84 cm length and the maximum thickness of the fuselage is 7.5 cm. Fuselage size variation is shown in Fig.2.2.1. The fuselage gives main support to the rotor blades at both the ends and the tail plain is attached at the rear end of the fuselage. The material used for making the fuselage is Coroplast. The propulsion system is fixed at front of the fuselage which plays a main role in producing forward flight.

Fig.3.2.1Fuselage size variation

3.3. Tail Plane

In order to acquire longitudinal and directional stability of the aircraft, horizontal and vertical stabilizers are incorporated in the rear end of the fuselage. Since gyrocame is a low speed aircraft, there is a necessity that it has excellent glide ratio or lift to drag ratio. High glide ratio is obtained by using T tail configuration shown in Fig.2.3.1. T-tail designs have become popular on many light and larger aircraft, especially those with aft fuselage-mounted engines because the T-tail configuration removes the tail from the exhaust blast of the engines.

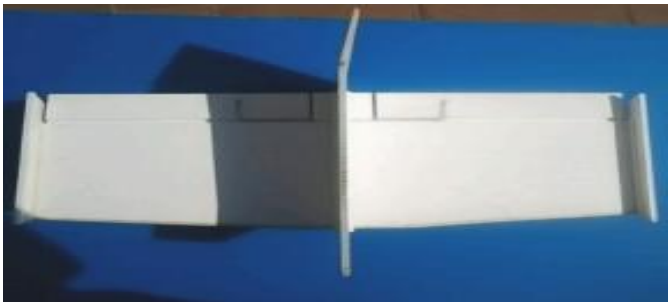

Fig.3.3.1Tail plain-T-Tail configuration

The horizontal stabilizer prevents up-and-down or pitching, motion of the aircraft nose. The length of the horizontal stabilizer is 51cm and width 17.4 cm. the elevator is also a part of this stabilizer which has 18cm length and 2.3cm width. Sub-fin is a part of tail plain and it is used as a vertical stability. These sub-fins are used to increase the stability of the tail plain. The height of sub fin is 6cm and length at rear is 12.5cm and at front is 16.5cm. The vertical stabilizers in the aircraft is typically found on the aft end of the fuselage or body, and are intended to reduce aerodynamic side slip and provide direction stability. It has breadth of 28cm and rear length to be 16.5cm and front length to be 20.5cm.

Fig.3.3.2.Fabricated Model

3.4. Other Components

Mini DV is one of three common digital formats used in sound and picture recording. Using digital technology, Mini DV captures video and audio on high-density cassette tapes. This format is very popular, as it delivers sound and video that is decidedly sharp and high quality. Transferring video to a PC can be accomplished using an IEEE-1394 interface, commonly known as FireWire or I. Lin.

The motor used here is a Brushless DC motor. This motor could be characterized as the modern kind of DC motor. The motor is been selected in such a way that it has the pulling capacity of 1.5kg-2kg.Since our aircraft total weight is estimated to be 1.5kg, a brushless motor of C3530 Model type which has the pulling capacity is been used. The total capacity of the motor is 30amps.

An electronic speed control or ESC is used which is a device mounted onboard an electrically-powered R/C model in order to vary its drive motor's speed, its direction and even to act as a dynamic brake in certain controllers, perhaps even antilock braking.

RC servos are composed of an electric motor mechanically linked to a potentiometer. The servos we have used here is of 9gms weight. The voltage varies from 4.826volt to 6 volts. It has a maximum torque capacity of 1.3 to 1.5 kg and the speed limit is 0.1 to 0.008 sec per 60 degree

The transmitter used here is mode 2 (left hand throttle) with 6 channels. The radio frequency range is 2.40 to 2.48 GHz with a bandwidth of 500 Hz and sensitivity of 1024. 12V DC power supply is used. The receiver used here has a RF power less than 20db with 6 channels.

IV. PERFORMANCE PARAMETERS CALCULATION

The mission profile of gyrocame involves taxiing, take off, climb, cruising, loiter, cruise, descent and ground roll. The weight plays an important role in designing any kind of aircraft. Here, the overall weight is found by summing up all the other weights, which is given by,

$$\begin{aligned} W_o &= W_e + W_m + W_p \\ &= 1310+140+50 \\ &= 1500\text{gms} = 1.5\text{Kg} \end{aligned}$$

Where W_o is overall weight, W_e is empty weight, W_m is motor weight and W_p is the payload weight. The velocity at which the aircraft stalls is known as stalling velocity. It is given by the formula,

$$V_{stall}=[(2/\rho_\infty)\ (w/s)\ (1/c_{lmax})]^{(1/2)}$$

Substituting the values the required V_{stall} is 8.41 ft/sec. The flare velocity is given as 1.15 times the stall velocity. So V_f is 9.67lb/ft^2. The Flight path radius during flare is given by,

$$R = V_f^2/0.2g = 47.6 \text{ ft}$$

The aspect ratio, defined as the square of the wingspan, b (15.2) divided by the area, S (2.9) of the wing, is 5.2. The wing loading is calculated to be 0.180. The turning radius which represents the size of the smallest circular turn that the vehicle is capable of making is calculated from the equation,

$$R = \frac{1}{1/2\, \rho g Cl}\left(\frac{W}{S}\right)\left(\frac{n}{\sqrt{n2-1}}\right) = 14ft$$

The rate at which an aircraft turns is known as turn rate. Turn rate is given by the formula,

$$\psi = g\sqrt{\frac{1/2\, \rho S Cl}{W}}\sqrt{\frac{n2-1}{n}} = 0.38 rad/sec$$

The performance results calculated was found to have higher efficiency than the past models which was designed and fabricated. The comparison between the two fabricated models are shown in the below Table 3.1

TABLE 3.1 Comparison between different configurations

Specifications	Old Configuration	New Configuration
Gross Weight(kg)	1.7	1.5
Cruise Speed(m/s)	7	9.5
Maximum Speed(m/s)	6.5 to 9.5	8.5 to 11.5
Maximum Operating Height(ft)	15	25
Disc area(mm)	50	100

Pitch angle, Solidity of the blades are the major factors that will influence the efficiency of autogyro. The solidity of the blades was found to be higher which is defined as the ratio between the total blade areas to the disc area. The drag is reduced greatly by increasing the wing support span, rotor disc area and decreasing the rotor blade thickness.

V. CONCLUSION

Hereby we conclude that gyrocopter which has a good solidity of the blades, high ratio of tip speed to forward speed and a desired disc area is one of the most efficient autogyro with features like effective flying at low speeds without losing its stability. The loading is increased in order to maintain the sufficient tip to forward speed. Usage of twin rotor had reduced the complicated linkage of the rotor head like in the single rotor auto gyro. This configuration is very tolerant of failures like at times during the loss of a rotor blade. The critical short comings of Autogyro include a large amount of drag (interference & induced) production. This has been overcome in gyrocame by the use of fairings in the wing & rotor blade edges for interference drag and increasing the wing span for induced drag.

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