Design & Development of Coaxial Wing Micro Air Vehicle

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***Abstract*— The main objective of this work is the systematic description of the current research and development of small or miniature unmanned aerial vehicles and micro aerial vehicles, with a focus on rotary wing vehicles. In recent times, unmanned/Micro aerial vehicles have been operated across the world; they have also been the subject of considerable research. In particular, UAVs/MAVs with rotary wings have been expected to perform various tasks such as monitoring at fixed points and surveillance from the sky since they can perform not only perform static flights by hovering but also achieve vertical takeoffs and landing. Helicopters have been used for personnel transport, carrying goods, spreading information, and performing monitoring duties for long periods. A manned helicopter has to be used for all these duties. On the other hand, unmanned helicopters that can be operated by radio control have been developed as a hobby. Since unmanned helicopters are often superior to manned helicopters in terms of cost and safety, in recent years, accomplishing tasks using unmanned helicopters has become popular.**

Considerable expertise is required to operate unmanned helicopters by radio control, and hence, vast labor resources are employed to train operators. Moreover, it is impossible to operate unmanned helicopters outside visual areas because of lack of radio control, and the working area is hence limited remarkably. For solving the above problems, it is necessary to realize autonomous control of unmanned helicopters. However, no general method for designing the small unmanned helicopters has been developed yet – today, various design techniques by different study groups using different helicopters exist. In this thesis the conceptual design process is explained. Using CATIA V5 software model is design & using ANSYS software stress & force analysis is done on rotor blade material to justify that blade material & blade dimensions is appropriate to develop the model accordingly.

***Keywords*— Micro Air Vehicle, Unmanned Air Vehicle, Fuselage, rotor blade.**

I. INTRODUCTION

For over 40 years the helicopter has played an important role in both military and civilian air transportation. In this thesis we will discuss the basic principles of modern helicopter aerodynamics & basic design method require to develop micro air vehicles. The field of helicopter aerodynamics is a vast one and includes a number of current research problems that are extremely important in their own right.

In general, the helicopter is designed to be able to perform tasks that fixed wing aircraft cannot do, specifically to take off and land vertically (VTOL) and to hover. There are four flight regimes in which the helicopter operates. First, there is hover, in which the thrust generated by the rotor blades just offsets the weight, and the helicopter remains stationary at some point off the ground. The second flight regime is vertical climb, in which additional thrust is required to move the helicopter upward. Third, there is vertical descent, a more complicated flight regime because of the presence of both upward and downward flow in the rotor disk which can induce significant blade vibration. Finally, there is the condition of forward flight, in which the rotor disk is tilted in the flight direction to create a thrust component in that direction. In forward flight, the component of the thrust in the forward flight direction must overcome the drag. Forward flight is characterized by the advance ratio, $\mu = \frac{V}{\Omega R}$ where V is the forward flight speed, Ω is the angular speed of the rotor, and R is the rotor radius. Typically, design constraints suggest $\mu \leq 0{:}4$. Landing is a combination of forward flight and vertical descent.

II.METHODOLOGY

At first general formulae's used to design a micro aerial vehicle weighting less than 100 g & length not more than 15 cm are to be present. Considering gross weight as a constant parameter following parameters are to be find out 1.Total power, 2.Rotor Diameter ,3.Tail Rotor Diameter , 4.Fuselage length ,5.Airframe Overall length, 6.Maximum speed ,7.Rate of climb

To check the hover performance Lift force on a blade , Drag force , Centrifugal force are to be calculated based on formulae's. After finding different parameters model is to be constructed in CATIA software. The next step is the analysis of different parts of MAV by using CFD or ANSYS software. Then a model is developing to test the flight of micro air vehicle.

III.DESIGN PROCEDURE

Considering gross weight as 40 g following parameters are finded out

1.Relation between take off total power (kW) & gross weight (kg)

$P_{TO}^{\text{Coaxial UAV r}} \approx 0.0764.W_O^{1.1455}$ =1.19 W

2. Relation between Rotor Diameter in (m) & gross weight in (kg)

$D^{\text{Coaxial UAV}} \approx 0.4331.W_O^{0.385}$ = 12.5 cm

3. Relation between Tail Rotor Diameter in (m) & gross weight in (kg)

$D_{TR}^{\text{Coaxial UAV}} \approx 0.0886.\ W_O^{0.393}$ = 2.5 cm

4. Relation between Main Rotor Diameter in (m) & Fuselage length in (m)

$L_F = 0.824.D^{1.056}$ = 9.1 cm

5. Relation between Main Rotor Diameter in (m) & Airframe Overall (Rotor Turning) length in (m)

$L_{RT} = 1.09.\ D^{1.03}$ = 12.8 cm

6. Gross weight of vehicle = 40 g

7. Relation between gross weight in(kg) & maximum speed in (km/hr)

$V_{max}^{\text{Coaxial UAV}} = 78.5.W_o^{0.137}$ = 14.02 m/sec

8. Relation between rate of climb in (m/min) & gross weight in(kg)

$V_c^{\text{Coaxial UAV}} = 99.5.W_o^{0.268}$ = 0.699 m/sec

9. The lift force is calculated as

$F_L = 0.5\times C_L\times\rho\times Vmax^2\times A$=0.1645 N

Total lift force is calculated as

$F_{L(t)} = F_L$ x 2= 0.329 N

Minimum condition for MAV to fly is weight should be equal to lifting force created by rotor blades

We know that lifting force in rotors pair with same rotors decreases with increasing of distance between rotors. This decreasing is about 20 % at increasing of rotors distance 60 %. Contrary to this lifting force changes insignificantly in rotor pairs with different length.

On contrary, the lifting force can be improve by decreasing the distance between rotors up to some limit, here we consider that distance between rotor is decease by 18 mm normally it was 30 mm so lifting force will increase by from 0.329 N to 0.3948 N

i.e. Total Lift Force is 0.3948 N

10. Drag force is given by

$F_D = 0.5\times C_D\times\rho\times Vmax^2\times A$ =0.05141 N

11.The centrifugal force is given by:

$F_C = M_b\Omega^2R$ = 0.010938 N

Where M_b = Mass of blade   Ω = actual speed of rotor blade

12. Number of teeth of main gear =85

Number of teeth of pinion gear = 07

13. Longitudinal length from hinge to free end: 9 cm

Blade width at free end: 1cm

Blade width at hinged end: 2.2 cm

Blade angle = 22^0

The thickness of the blade is very small

14. The power is supplied for the model from a 3.7 V 150mAh Li ion battery & motor is of 5920 rpm. It is reduced to 394.66 rpm by gear reduction.

Using Above design parameters CAD model is constructed & fabrication is done.

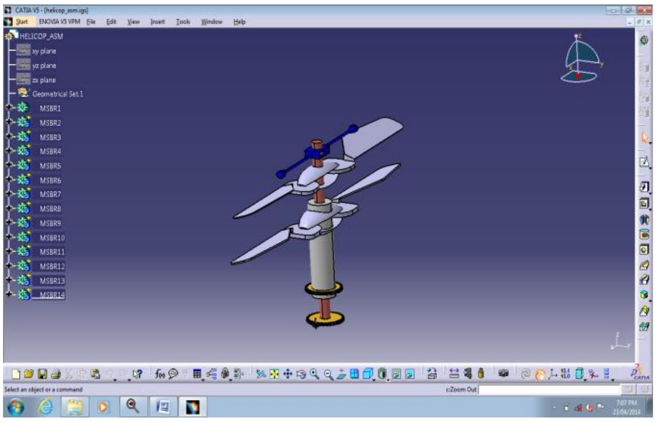

Fig.1.CAD model of mechanism used in MAV

Fig.2. Lower Rotor Blades

Fig.3.Upper Rotor Blade along with stabiliser Bar

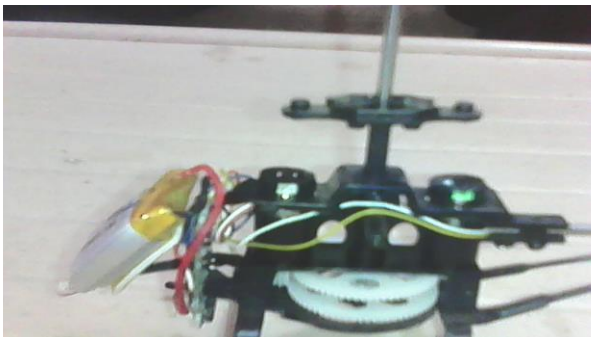

Fig.4.Assembly of Mechanism Used in MAV

IV.RESULT & DISCUSSION

Analysis is to show the stress and strain acting at different parts of the rotor blade. The software used for this is ANSYS. The material given for the blade is Polystyrene. The properties of the polystyrene material are given in ANSYS and the CATIA model is meshed using Quad (6 node) element type. The properties of polystyrene used are:
Density: 1.05 g/cm3
Thermal conductivity: 0.036 W/(m·K)
Tensile strength: 52 MPa
Young‟s modulus: 3300 MPa
Linear expansion coefficient: 8×10-5/K

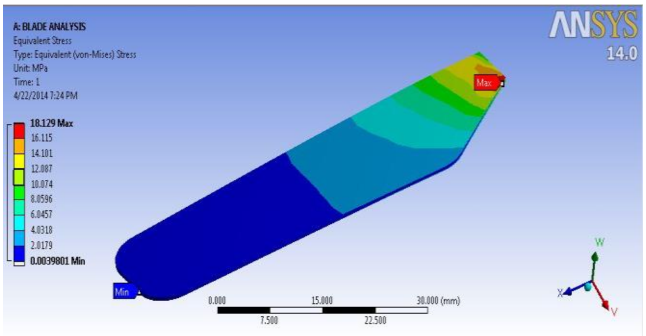

Fig.5: Shows Von-Mises Stress Analysis of Blade

Following result are obtained from analysis
Maximum Stress: 18.129 MPa
Minimum Stress: 0.0039801 MPa

As maximum value of tensile strength of material of blade is 52 MPa design is considerable

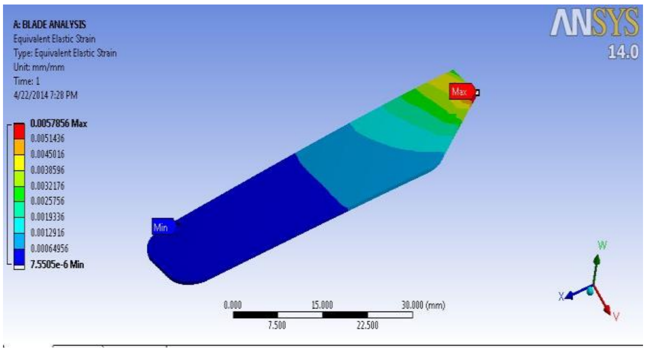

Fig.6: Shows Von-Mises Strain Analysis of Rotor Blade

Following result are obtained from analysis
Maximum Strain: 0.0057856 mm/mm
Minimum Strain: 0.00064956 mm/mm
Above results are considerable for blade material.

V.CONCLUSION

1. The ANSYS analysis for von-Mises stress in Fig.12 shows that the hinged tip of the rotor blade experiences a stress in the limit from 18.129 MPa to 0.0039801 MPa. As this range of values is less than the tensile strength of polystyrene, which is 52 MPa, therefore no signs of fracture are observed and the analysis is safe. The free tip of the rotor blade experiences a very low von-Mises stress of 0.0039801 MPa, which is acceptable.

2. The ANSYS analysis for von-Mises strain in Fig. 13 shows that the hinged tip of the rotor blade experiences a strain in the limit from 0.0057856 to 0.00064956 and the free tip experiences minimal strain of 1.8872×10-8.

3. Speed of the rotor is obtained in section 4.6 as 394.66 rpm and at that speed of the rotor, the lift generated is found to be 0.3948 N in section 5.1.2. This lift force is found to be greater than the weight of the helicopter, which is found to be 0.3924 N in section 5.1.1. Thus, the lift force generated is calculated to be greater than the weight of the helicopter, which is the necessary condition for take-off. This result will confirm in the fabricated model which takes off as expected.
2. Speed of the rotor in hover condition is found out be 215.4 rpm in section 5.3. This is the speed at take-off state of the helicopter. Thus, it is concluded that the speed of the rotor must lie between the limit values of 215.4 rpm and 394.66 rpm for the helicopter to be in flight. Any speed less than 215.4 rpm will result in the lift force to be less than the weight for which the helicopter will not take off or if in flight, will fall down.

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