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Design & Analysis of Vertical Takeoff and Landing Vehicle (VTOL)

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Abstract

VTOL aircraft is for vertical hover, landing and horizontal flight, The paper deals with the innovation that relates to manned or autonomous vertical takeoff and landing (VTOL) vehicles and proposes various models for hoverbike This Paper also deals with static structural analysis of various proposed frames of hoverbike and comes out with conclusion of most suitable frame for constructing hoverbike Along with the validation of the simulation carried out ANSYS.

Keywords: VTOL, Hoverbike Design, FEA, Beam deflection, ANSYS, Dual copter, Multicopter, Flying bike

Introduction

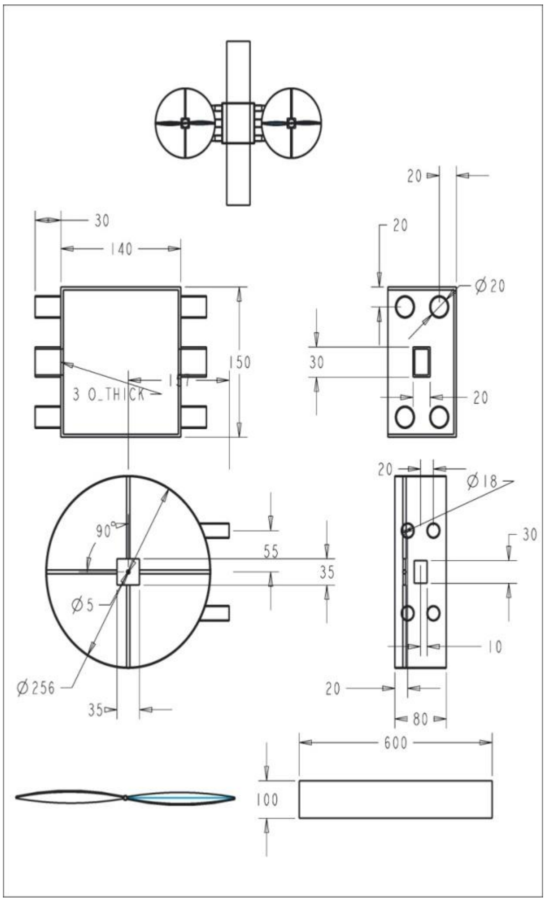
Vertical takeoff and landing vehicles are known for their vertical thrust hovering and landing at the same place without need of runway. It has found its importance with large area of research in recent years. It can be implemented in areas of unexplored territory. It can come in various sizes and can be remote controlled, autonomous or manned controlled. The design of such VTOL is of prime important as large amount of forces acts in the air which is to be considered while designing the VTOL. Besides the weight is of great concern while designing it, as large lift force is to be created for lifting that weight so high power to weight ratio should be opted. Number of motors, size of rotor, speed and torque of motor, type of battery, type of motor all this factors should be considered while designing VTOL. This paper deals with the designing of various frame for dual rotor VTOL and analyse it under static force conditions and check its feasibility. We have selected Hoverbike a dual copter VTOL, simplest VTOL as suggested in the paper (Aditya Intwala, Yash Parikh, 2015).

Review

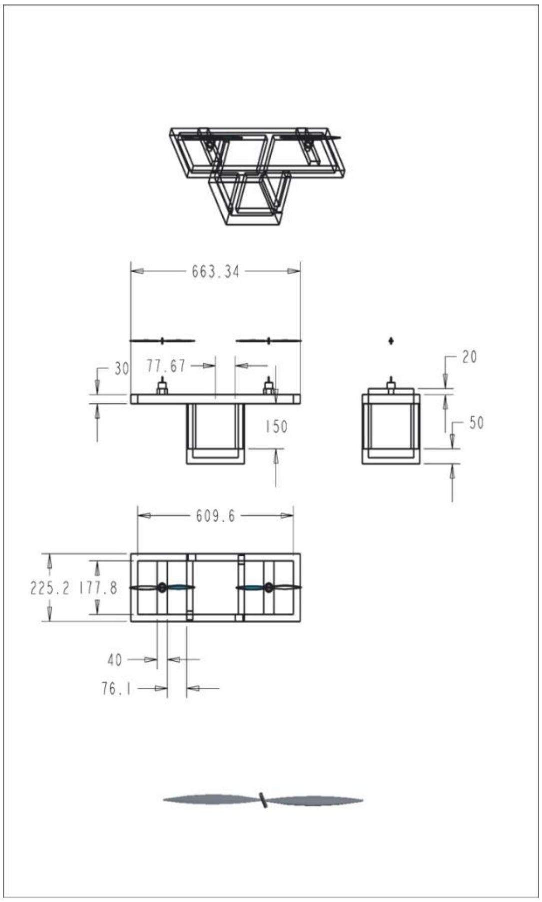
The concept of VTOL has got pace since past 50 years. Initially they were short run takeoff vehicle (STOL). But due to more research in this field has devised various configuration of VTOL vehicle on large scale or small scale, manned or unmanned. Most of which is reviewed in the paper by Aditya Intwala et al. (2015). One of simplest configuration is of Hoverbike a type of Dualcopter. Hoverbike is concept VTOL which is flying vehicle. It uses two rotors instead of wheel. This generates thrust for lifting and manoeuvring purpose. It looks similar to chopper. Various designs are drafted in the US patent (Sanders Jr John K, Sanders J Kenneth, Aviles Jr Arturo, Aviles Arturo F, 2006).

Model Design & Analysis

First step in designing the VTOL vehicle is to design the chassis or frame of the hoverbike on which various attachments and rotor is to be fitted. For a small scaled unmanned RC hoverbike three models were drafted according to the requirement. The Figure 1 (a), (b) & (c) shows the 2D model drafted along with dimensions.



(a)



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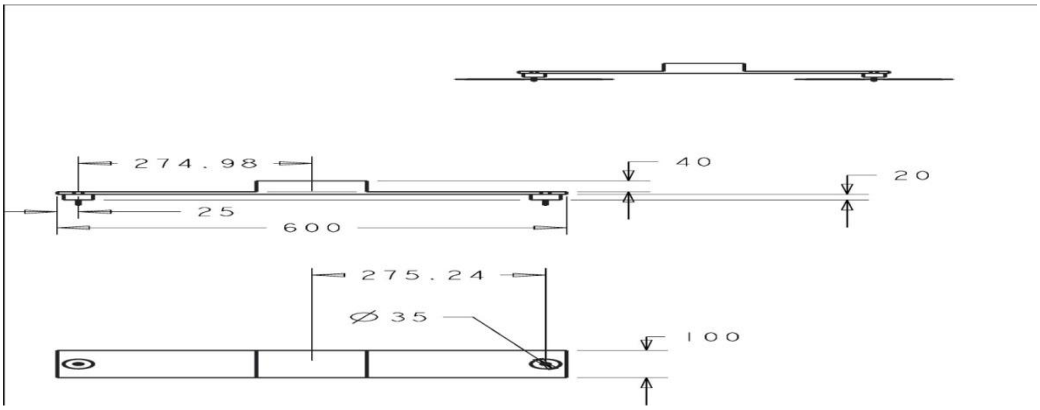
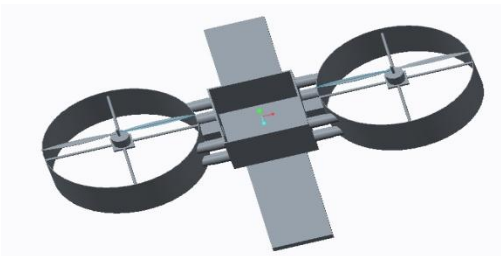


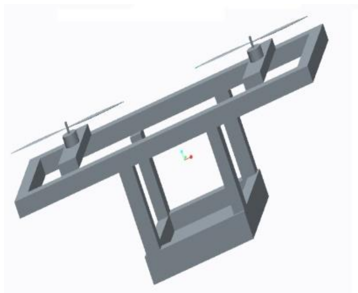
(c)

Figure 1: (a) Model 1 (b) Model 2 (c) Model 3

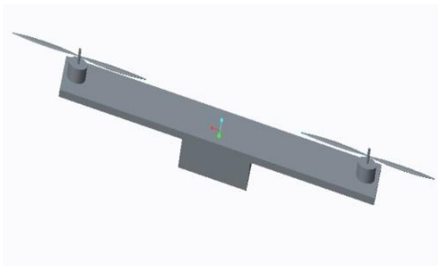
Now these models were needed to be modelled in 3D modelling software in order to carry out analysis on the frame under static conditions. FIGURE 2 (a), (b) & (c) shows three models modelled in Creo 2.0 according to the dimensions.



(a)



(b)



(c)

Figure 2: (a) Model 1 (b) Model 2 (c) Model 3

These models were analysed in ANSYS under Static Structural analysis. Various forces act on the chassis so there is need to know if the frame could withstand the force or it fails under force. The main conclusion from analysis would be which model could give minimum deformation under load and develop minimum stress. Considering thrust forces and weight

Table 1: Force Under Consideration

Force	Type	Magnitude
A	Fixed Support	NA
B	Thrust Force	9.18 N
C	Thrust Force	9.18 N
D	Motor Weight	0.6867 N
E	Motor Weight	0.6867 N

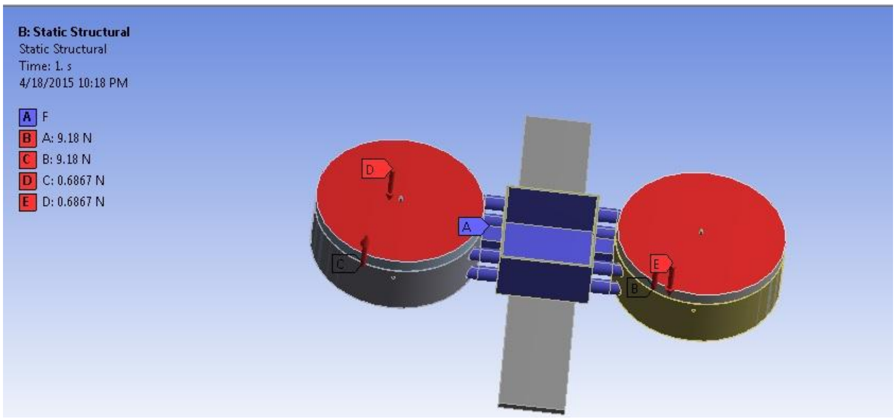
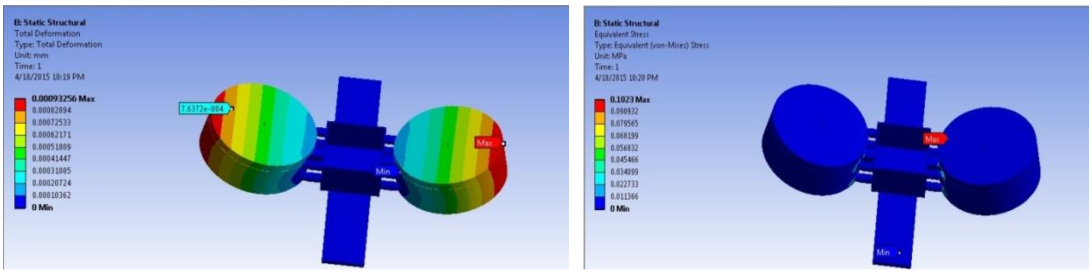


Figure 3: Force Consideration

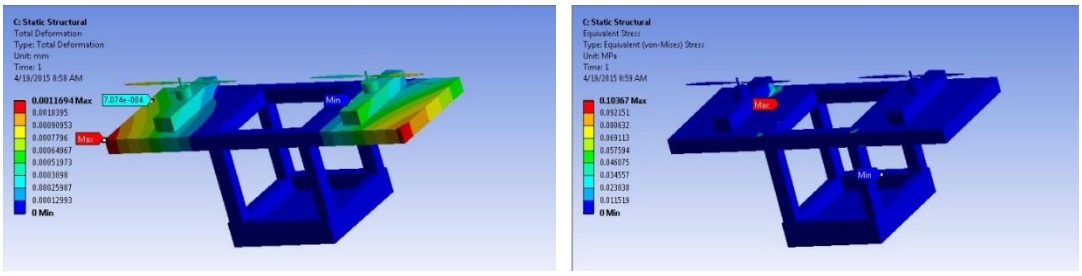
Results and Discussion

Results obtained by carrying out ANSYS simulation of the above three Models under given load conditions are as follows



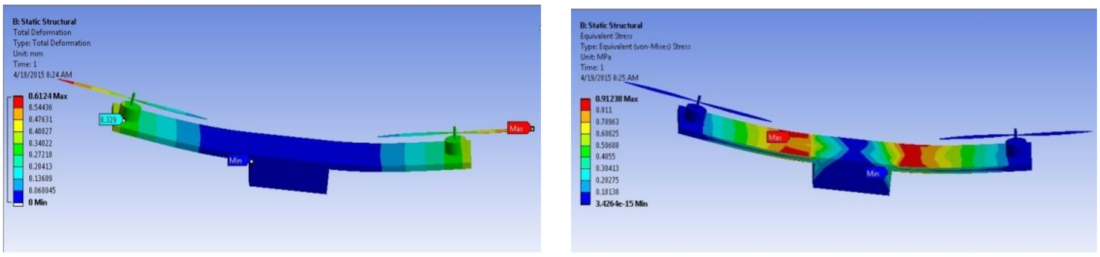
(a) (b)

Figure 4: (a) Model 1 Total Deformation (b) Model 1 Von Misses Stress



(a) (b)

Figure 5: (a) Model 2 Total Deformation (b) Model 2 Von Misses Stress



(a) (b)

Figure 6: (a) Model 3 Total Deformation (b) Model 3 Von Misses Stress

From the above ANSYS simulated results we can summarize following deformation and stress in the Models.

Table 2: ANSYS Simulation Summary

Model	Deformation (mm)			Stress (MPa)	
	Minimum	Point Of Interest	Maximum	Minimum	Maximum
Model 1	0	0.0007637	0.00093256	0	0.1023
Model 2	0	0.0010395	0.0011694	0	0.10367
Model 3	0	0.329	0.6124	3.4264e-15	0.91238

In Table 2 Point of interest column in Deformation Section shows the magnitude of deformation at the point of application of force or point of importance. As seen from the simulation the Model 1 has minimum total deformation in mm and minimum maximum stress developed among all the three simulated Models. While the Model 3 has highest of both values i.e. maximum total deformation in mm and maximum stress developed among all the three models.

Validation

Now in order to validate our results obtained from the simulations of all three models consider a Uniform cross section beam for all the three models and then calculate the deformation for the point of interest with the help of deflection of cantilever beam with point load. Due to symmetry on both sides consider one side of beam.

Model 1:

P= 9.123 N
E= 4100 N/mm^2 (PVC)
L= 227 mm
B= 254 mm
D= 80mm
$I = \frac{BD^3}{12}$

Figure 7: Model 1 Beam Consideration

$$I = \frac{(254)*(80)^3}{12} = 10837333.33 \text{ mm}^4$$

$$\delta = \frac{PL^3}{3EI} = \frac{(9.123)*(227)^3}{3*4100*10837333.33} = 0.0008005 \text{ mm}$$

Model 2:

P= 9.123 N
E= 10300 N/mm^2 (Wood)
a = 96 mm
b = 130 mm
B= 226 mm
D= 30 mm
$I = \frac{BD^3}{12}$

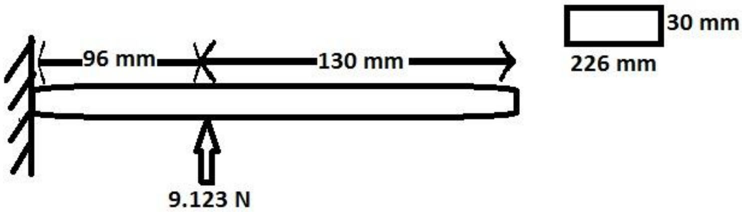


Figure 8: Model 2 Beam Consideration

$$I = \frac{(226)*(30)^3}{12} = 508500 \text{ mm}^4$$

$$\delta = \frac{Pa^3}{3EI} * \frac{(1+3b)}{(2a)} = \frac{(9.123)*(96)^3}{3*10300*508500} * \frac{(1+(3*130))}{(2*96)} = 0.0010459 \text{ mm}$$

Model 3:

P= 9.123 N
E= 10300 N/mm^2 (Wood)
L= 210 mm
B= 100 mm
D= 10 mm
$I = \frac{BD^3}{12}$

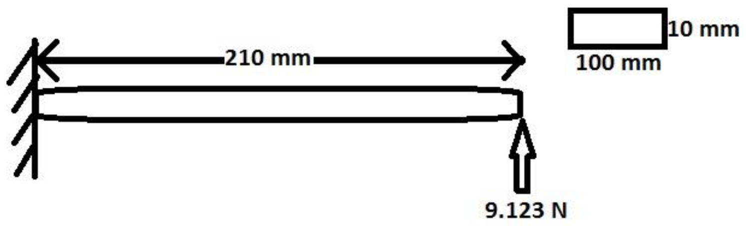


Figure 9: Model 3 Beam Consideration

$$I = \frac{(100)*(10)^3}{12} = 8333.33 \text{ mm}^4$$

$$\delta = \frac{PL^3}{3EI} = \frac{(9.123)*(210)^3}{3*10300*8333.33} = 0.32810926 \text{ mm}$$

Conclusion

From the simulated ANSYS analysis and analytically calculated values we can find out percentage error present due to which actual answer varies with the simulated answer. The Table summarize the values obtained from ANSYS Simulation and analytically calculated values along with percentage error.

Table 3: Percentage Error

Model	ANSYS Simulated	Analytically Calculated	Percentage Error
Model 1	0.0007637	0.0008005	4.818 %
Model 2	0.0010395	0.0010459	0.615 %
Model 3	0.329	0.32810926	0.27 %

From the above table we can see that percentage error between calculated and simulated values is below 5 % for all the three models. This error occurs due to the fact that we have assumed constant cross section beam for analytical calculations while in real the model has variable cross section. Hence all Three Models are validated.

Besides Model 1 has least Total Deformation in mm and has least stress developed among all the three models hence Model 1 is best suitable for VTOL application among all 3 models.

Acknowledgement

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