Numerical Estimation Of Ultimate Specification Of Advanced Multi-Rotor Unmanned Aerial Vehicle

P. Jagadeeshwaran, Dr. V. Natarajan, Vijayanandh R*, Senthil Kumar M, Raj Kumar G, Raajaadurai R, Abdulkader M, Harimeyyan M M, Mathan Kumar S, Naveen A

Abstract: Advanced multi-rotor UAVs are emerging one, in which the complex maneuvering is achieved with the help of tilting mechanism. This article deals with the numerical estimation of maximum specification of Tilt-Hexacopter, which intended for critical applications. Maximum forward speed and rate of climb are the parameters fundamentally taken for spacecritical study. The reference components of Tilt-Hexacopter are modelled by using CATIA V5 and the numerical simulations are carried out with the help of ANSYS Workbench 16.2, in which drag force, coefficient of drag are mainly considered as evaluation parameters. Finally, Comparative analysis have been carried out for different case as well as different manoeuvring, in which the maximum forward speed is predicted as 40 m/s and maximum rate of climb is predicted as 30 m/s.

Index Terms: CFD, Lift, Specification, Thrust, Tilt-Hexacopter, Forward Speed, VTOL

1.1 MULTI-ROTOR UAV

Nowadays unmanned aerial vehicles (UAVs) are an important part of scientific study in both military and space. As a substitute for human-piloted vehicles they are advantageous in protecting human life from multiple dangerous environments. The unreliability's in tough circumstances are much higher than their counter parts. Especially, multi-rotor UAVs like Tricopter, Quadcopter, and Hexacopter are plays the vital role in complex application. While undergoes the complex applications, the multi-rotor UAVs are affected by structural failures or else insufficient to finish the complex surveillance. In order to execute the perfect surveillance in the complex region, the multi-rotor UAVs need to undergo engineering analyses in the perspective of complex test. This work deals the estimation of advanced multi-rotor UAV's [Tilt-Hexacopter] specification with the help of numerical simulation [1].

1.2 Summary

From the survey, the major problems in the advanced multi-rotor UAVs [Tilt-Hexacopter] were analyzed, in which the prime problems are Tilt-Hexacopter does not provide safety to its parts, the life cycle of the components is less, and it does not have safe landing and takeoff. To overcome these problems the Tilt-Hexacopter has to undergo numerical simulation in order to estimate its ultimate specification details. The ideal alternative choice for critical environment workers is Tilt-Hexacopter, which might survive at any critical environment operation such as border surveillance, forest surveillance, etc. Also, from the field work it is understood that, specification study of UAVs are mandatory in order to segregate the UAVs implementation in different applications and thereby learned that advanced numerical simulation is the only way to simulate the aerodynamics behaviour of Tilt-Hexacopter while undergoing critical maneuvering in the critical environment [2].

2 TILT-HEXACOPTER

2.1 Specification

Traditionally in fixed wing UAV, lot of research has been done to incorporate vertical take-off and landing (VTOL) feature and to increase its manoeuvrability. The alternative was the rotary wing UAV which is more manoeuvrable and has the VTOL Feature. The problem associated with rotary wing UAV is that their efficiency and retreating blade stall. Hence the solution for existing problems in fixed-wing and rotary wing UAVs is an advanced UAV, which should have the capability to undergo VTOL as well as high forward speed. The concept used is in this hybrid UAV is tilt rotor mechanism, in which the proposed VTOL Tilt-Hexacopter consists of 6 motors, in which each propeller is capable of providing maximum of 500 gram thrust in order to lift the 1.5 kg Tilt-Hexacopter. It has a stable platform, higher efficiency and can attain higher speeds than a normal multi-rotor UAVs with the help of its tilting mechanism. A positive modification in the specification of UAVs is the best way to fulfil the upcoming complex requirements, in which high lifetime, high forward speed, long endurance and range, stable surveillance are the prime. This paper deals the estimation of high forward and vertical speeds of the Tilt-Hexacopter with the help of advanced numerical simulations [3].

2.2 Conceptual Design

The complete 3-Dimensional diagram of the UAV is the consolidated output from its conceptual design. In order to construct a successful 3-D Tilt-Hexacopter, certain preliminary steps are needed to complete, which are outer boundary of Tilt-Hexacopter, complete details of components, location of components and their complete dimensions, centre of gravity location, centre of thrust estimation. In this Tilt-Hexacopter, all the preliminary steps were completed and the finalized 3-D diagram is modelled with the help of CATIA V5, which are shown in the figure 1 and 2. Figure 1 and 2 shows the different operational mode of Tilt-Hexacopter, in which HTOL mode is shown in the figure 2 and VTOL mode is revealed in the figure 1 [4, 5].
3 NUMERICAL SIMULATIONS

3.1 Numerical Methodology and its Physics

Computational Fluid Dynamics (CFD) deals the prediction of fluid behaviour on the given object with the help of computerized set of algebraic equations. In which, fluid such as gas and liquid properties are governed by partial differential equations which represent conservation laws for the mass, momentum, and energy. The equations of fluid flow are based on fundamental physical conservation a principle, which primarily deals conservation of mass and conservation of momentum. Primarily four parameters are to be estimated, which are pressure, velocity in x, y and z directions then turbulence prediction is secondary parameter estimation. Conservation of principles are tool used to estimate primary parameters directly and indirectly helped to predict the turbulence behaviour. Currently numerical methods have been used as solve the fluid behaviour due to complex of conservation of principle. The main stages of ANSYS software simulation are pre-processing, in which formulate problem like geometry, equations, boundary conditions and construction of a control volume are completed. Solver stage involves the solving of primary parameters at nodes and elements using numerical simulations and finally the result execution and visualizing are done thorough post-processing [6, 7].

3.2 Boundary Condition

In numerical simulation, boundary conditions initiate the whole process. In this paper, pressure based solver is used because of Tilt-Hexacopter working environment, in which Tilt-Hexacopter comes under the low speed incompressible operation. Absolute system is selected in order to cover the whole system with the global coordinate system. Aerodynamics of UAV depends on Rotating propellers and its turbulence generation around the aircraft so prediction of turbulence in numerical simulation is mandatory process. This analysis used k-epsilon turbulence model, which is more capable to capturing the turbulence, flow separation with the help of its two equations such as kinetic energy of the turbulence and dissipation rate of turbulence. Generally, velocity inlet is more preferable artificial boundary conditions, which can able to predict flow behaviour of the low speed operation also pressure outlet has been suggested and used. After the assignment of artificial boundary conditions, the process of physical boundary conditions have been completed in which the no slip condition is given on the solid-fluid interaction surface on the Tilt-Hexacopter and free slip condition has been given to the exterior part of external domain. 101325 Pa has been given as operating pressure hence the value of gauge pressure is 0 Pa. Least square solution methodology is selected because of the unstructured mesh generation also higher order equation is selected in order to get high accurate results. Flow analysis over the Tilt-Hexacopter is complicated analysis, which may affect the numerical results and thereby unstable variation takes place in the output residual so relaxation factor has been reduced 20 % [8, 9].

3.3 Tilt-Hexacopter - VTOL: Velocity 30 m/s Result
Figure 3 and 4 shows the pressure variation on the entire Tilt-Hexacopter and velocity variation in the planner view respectively. Figure 5 show the drag plot of the Tilt-Hexacopter for the fluid velocity of 30 m/s, in this case drag estimation axis is Z-axis [10].

Figure 6 and 7 shows the pressure variation on the entire Tilt-Hexacopter and velocity variation in the planner view respectively. Figure 8 show the drag plot of the Tilt-Hexacopter for the fluid velocity of 35 m/s, in this case drag estimation axis is Z-axis [10].

3.4 Tilt-Hexacopter - VTOL: Velocity 35 m/s Result

3.5 Tilt-Hexacopter - HTOL: Velocity 30 m/s Result
Figure 9 and 10 shows the pressure variation on the entire Tilt-Hexacopter and velocity variation in the planner view respectively. Figure 11 shows the drag plot of the Tilt-Hexacopter for the fluid velocity of 30 m/s, in this case drag estimation axis is Y-axis [11, 12].

3.6 Tilt-Hexacopter - HTOL: Velocity 35 m/s Result

Figure 12 and 13 shows the pressure variation on the entire Tilt-Hexacopter and velocity variation in the planner view respectively. Figure 14 shows the drag plot of the Tilt-Hexacopter for the fluid velocity of 35 m/s, in this case drag estimation axis is Y-axis [13, 14].

3.7 Tilt-Hexacopter - HTOL: Velocity 40 m/s Result
Figure 15 and 16 shows the pressure variation on the entire Tilt-Hexacopter and velocity variation in the planner view respectively.

Figure 17 show the drag plot of the Tilt-Hexacopter for the fluid velocity of 40 m/s, in this case drag estimation axis is Y-axis [15, 16].

Figure 18 and 19 shows the pressure variation on the entire Tilt-Hexacopter and velocity variation in the planner view respectively.

Figure 20 show the drag plot of the Tilt-Hexacopter for the fluid velocity of 45 m/s, in this case drag estimation axis is Y-axis [17, 18, 19, and 20].

### 3.8 Tilt-Hexacopter - HTOL: Velocity 45 m/s Result

![Planar view of Velocity variation](image16)

![Planar view of Velocity variation](image19)

**Table 1**

COMPARATIVE ANALYSIS OF FORCE VALUES OF VELOCITY IN HTOL

<table>
<thead>
<tr>
<th>Velocity (m/s)</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-Axis (N)</td>
<td>0.129794</td>
<td>-0.152018</td>
<td>0.350575</td>
<td>-0.278742</td>
</tr>
<tr>
<td>Y-Axis (Drag) (N)</td>
<td>9.31158</td>
<td>12.7161</td>
<td>16.6126</td>
<td>20.9441</td>
</tr>
<tr>
<td>Z-Axis (Lift) (N)</td>
<td>0.1374944</td>
<td>0.160803</td>
<td>0.171466</td>
<td>0.336995</td>
</tr>
</tbody>
</table>

**Table 2**

COMPARATIVE ANALYSIS OF FORCE VALUES OF VELOCITY IN VTOL

<table>
<thead>
<tr>
<th>Velocity (m/s)</th>
<th>30</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-Axis (N)</td>
<td>0.289535</td>
<td>-0.31285</td>
</tr>
<tr>
<td>Y-Axis (N)</td>
<td>0.0252483</td>
<td>-0.026001</td>
</tr>
<tr>
<td>Z-Axis (Drag) (N)</td>
<td>32.761</td>
<td>46.0402</td>
</tr>
</tbody>
</table>
In HTOL operation, tilting mechanism contributes high forward thrust, which supports the drag comparison of different velocities. Thrust production by individual propeller is known, which provides the total thrust of the Tilt-Hexacopter and thereby comparison between total thrust and drag force are plays predominant role in the specification estimation [21, 22]. From the Table 1, it is understood that drag force varies from 1.5 kg to 2 kg for the velocity range of 40 m/s to 45 m/s. For VTOL case, the drag force induced for velocities of 30 m/s and 35 m/s are 3.34069 kg and 4.69479 kg respectively [23, 24].

4 CONCLUSION
The preliminary design calculation on the Tilt-Hexacopter was estimated for selection of components and thereby the design of the Tilt-Hexacopter is finalized and modelled by using CATIA V5. The numerical simulations on the Tilt-Hexacopter are carried out with the help of ANSYS Workbench 16.2, in which HTOL and VTOL operations plays the major role. From this numerical simulation, it is concluded that the maximum forward speed of 40 m/s and maximum vertical speed 30 m/s are the ultimate speeds of this Tilt-Hexacopter, in which withstanding capability due to drag force impact is the only evaluating parameter considered. This paper also suggests that instead of trial and error method production of multi-rotor UAV, production of multi-rotor UAV based on the numerical simulation results is best suitable way, which provides high lifetime with high probability of success.

REFERENCES
[19] M. Senthil Kumar, R. Vijayanandh, N. Kaviarasan, R. Dinesh Kumar, I. Adrin Issai Arasu and R. Kannani raja,


