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Optimization of UAV Wing for Better Performance

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Abstract

An Unmanned Aerial Vehicle (UAV) is an aircraft that can be controlled by a pilot on ground station or autonomouslyby pre-programmed flight plans.The UAV generally has a droppable payload.In case of agricultural UAV'sthe aircraft will unload the payload. The main advantage of UAV is that they can be developed, produced and operated at lower costs . The use of UAV's in the agriculture industry can be a Crop field scanningwith compact multispectral imaging sensors, GPS map creation through onboard cameras, Heavy payload transportation, Livestock monitoring with camera. In order to enhance the performance of UAV with electronics and payload, the wing of the UAV is optimized.

Keywords: *UAV, Optimization, aerodynamic characteristics, Endurance..*

1. Introduction

An Unmanned Aerial Vehicle (UAV) is an aircraft that can be controlled by a pilot on ground station or autonomously by pre-programmed flight plans.The UAV generally has a droppable payload. In case of agricultural UAV's the aircraft will unload the payload. The main advantage of UAV is that they can be developed, produced and operated at lower costs. In terms of saving in engines, airframes, fuel consumption, pilot training, logistic and maintenance it is high. The use of UAV's in the agriculture industry can be a Crop field scanning with compact multispectral imaging sensors, GPS map creation through onboard cameras, Heavy payload transportation, Livestock monitoring with camera.

Topology optimization is extensively used in industrial optimization tasks. The definitions of objective, constraints and the specifications of allowable design space are required. A Parameterization is not necessary as topology optimization will not distinguish between geometry and analysis model. The end result of this optimization determines the material distribution in the optimal design space.

2. Objective

Without payload condition, the thrust required to fly was high and is similar to with payload, so endurance of the UAV was low.

The main objective is to increase performance parameter of the UAV which is achieved by reducing the Thrust required.

3. Methodology

Thrust required calculation

1. A UAV is designed in CATIA for the further CFD analysis.
2. For the thrust calculation we must select a suitable turbulent model and grid that is independent of various numbers of elements. Drag is calculated using climbing conditions.
3. By assuming climb acceleration and substituting in climbing equations, the thrust required can be estimated.

4. Results & Discussions

Optimization of the wing

The tool used for airfoil is XFLR5 which is an analysis tool for airfoil, wing and plane operating at low Reynolds numbers. This software is used for analysis here, also to obtain the aerodynamic characteristics of the wing and tail of the UAV. The airfoil profile database which are imported are EPPLER420 for wing and NACA-0014 for tail and batch analysis is done in direct foil batch analysis for varying Reynolds number, number of polar is generated.
Fig. 1 shows the model wing and tail in XFLR5. The wing is a rectangular wing of EPPLER 420 airfoil of span 2 meters and rectangular tail of NACA-0014 airfoil of span 1meter. Distance between wing leading edge and tail leading edge is 1.09 meters.

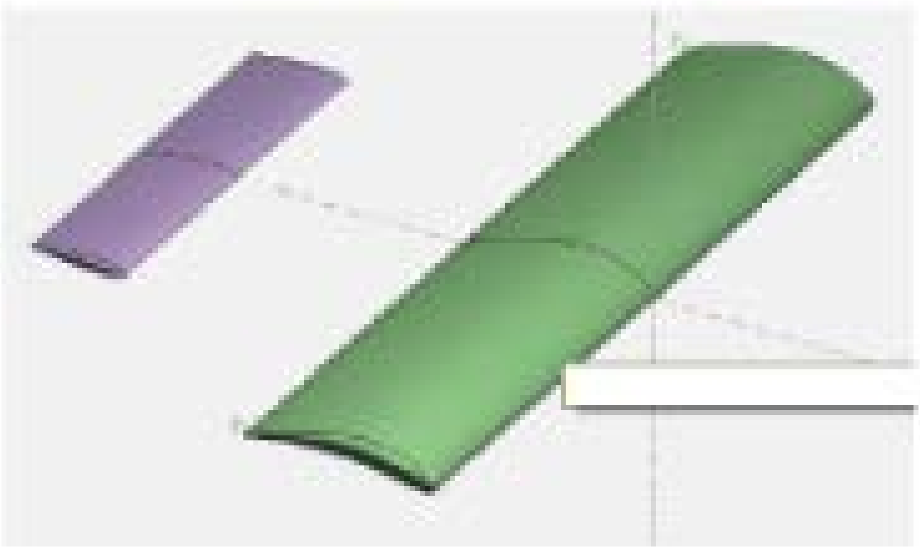

Fig. 1: Wing and Tail model in xflr5 of 2meters and 1meter span respectively**.**

The analysis yields, the pressure distribution on wing and tail in XFLR5 at α=0 and Velocity =11m/s.

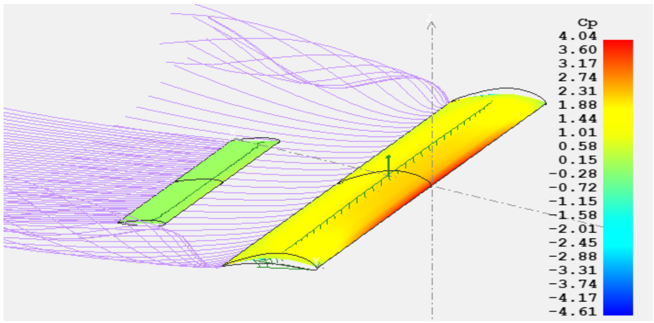

Fig. 2: Pressure distribution over wing and tail in xflr5

Table 1**:** xflr55 values of flight with and without payload conditions

Plane mass W (kg)	Span S (m)	$C_{L_{max}}$	V_{stall} (m/s)	V_{LO} (m/s)	V_{cruise} (m/s)	V_{TD} (m/s)
13	2	1.775	10.99	12.089	17.59	12.638
17	2	1.755	12.587	13.836	20.944	14.4647

Wing span is increased and wings are modified on XFLR5 software, where wing of 2.5m span is created by extending the wing of 2m span by 0.25m on both sides shown in Fig.3.

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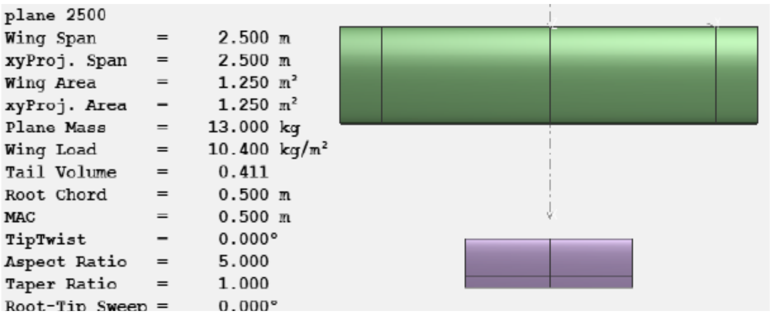
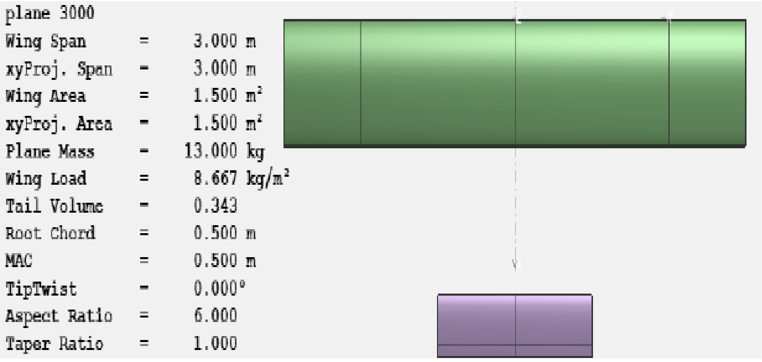


```
plane 2500
Wing Span       =     2.500 m
xyProj. Span    =     2.500 m
Wing Area       =     1.250 m²
xyProj. Area    -     1.250 m²
Plane Mass      =    13.000 kg
Wing Load       =    10.400 kg/m²
Tail Volume     =     0.411
Root Chord      =     0.500 m
MAC             =     0.500 m
TipTwist        -     0.000°
Aspect Ratio    =     5.000
Taper Ratio     =     1.000
Root-Tip Sweep  =     0.000°
```

Fig. 3: 2.5m Extended by 0.25m extension on both sides

Similarly, 3m wing is created by 0.5m extension on both side of wing as shown in Fig 4.



```
plane 3000
Wing Span       =     3.000 m
xyProj. Span    -     3.000 m
Wing Area       =     1.500 m²
xyProj. Area    -     1.500 m²
Plane Mass      -    13.000 kg
Wing Load       =     8.667 kg/m²
Tail Volume     -     0.343
Root Chord      =     0.500 m
MAC             =     0.500 m
TipTwist        -     0.000°
Aspect Ratio    =     6.000
Taper Ratio     =     1.000
```

Fig. 4: 3m Extended wing by 0.5m extensions on both sides

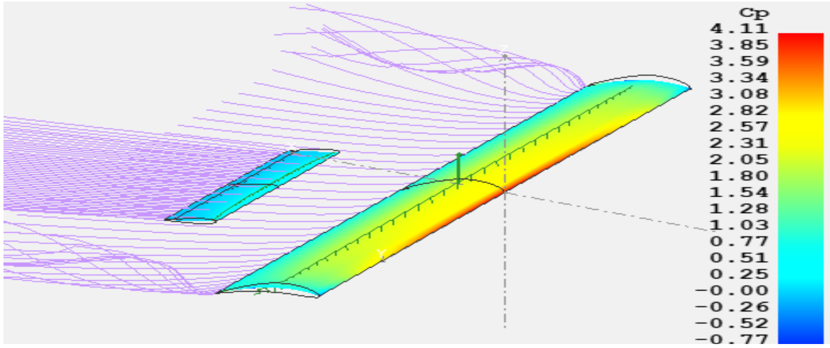


Fig. 5: Pressure distribution on 2.5m span wing in xflr5 software

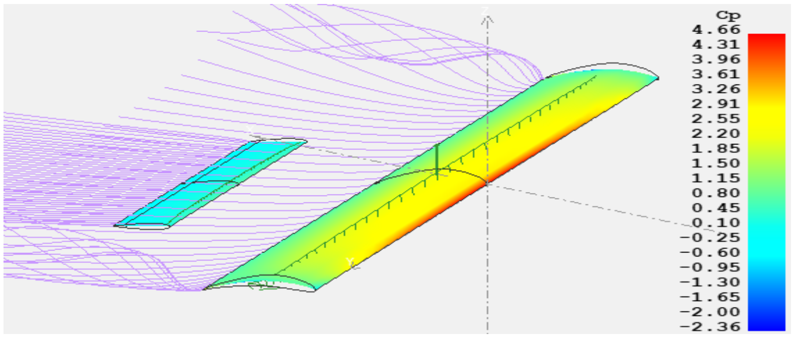


Fig. 6: Pressure distribution on 3m span wing in xflr5 software

Form the characteristic graphs in Fig 7, red and green line indicates 3m and 2.5m span respectively

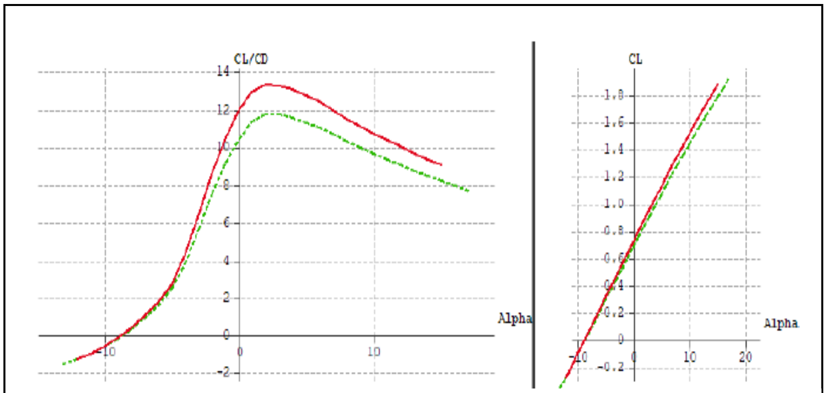


Fig. 7: Graphs of cl/cd vs α and cl vs α for various wing spans

Table 2: flight conditions with and without payload

Span (m)	$C_{L_{max}}$	$C_{L_{cruise}}$	V_{stall} (m/s)	V_{LO} (m/s)	V_{cruise} (m/s)	V_{TD} (m/s)
Without payload W=13kg						
2	1.775	0.633	10.99	12.089	17.59	12.638
2.5	1.8	0.680	9.71	10.68	15.8	11.16
3	1.876	0.718	8.68	9.548	14.04	9.982
With payload W=17kg						
2	1.775	0.633	12.587	13.836	20.944	14.4647
2.5	1.8	0.680	11.109	12.22	18.07	12.775
3	1.876	0.718	9.93	10.923	16.056	11.42

CFD Analysis of UAV

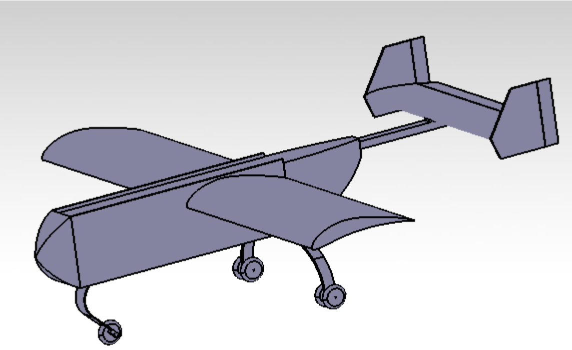


Fig. 8: Solid CATIA model of UAV

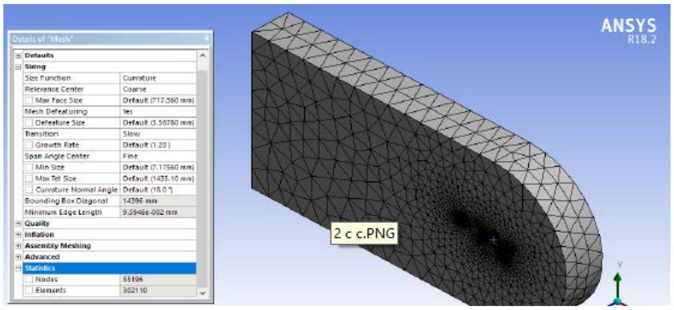
UAV of 2m span is modeled in CATIA software. The created model is encloses by a volume and then by Boolean subtract operation. By using CFD flow analysis in ANSYS fluent drag at climb can be calculated. But to find optimal meshing conditions and methods few trials are required.

Boundary Conditions

Table 3: Boundary conditions for CFD analysis

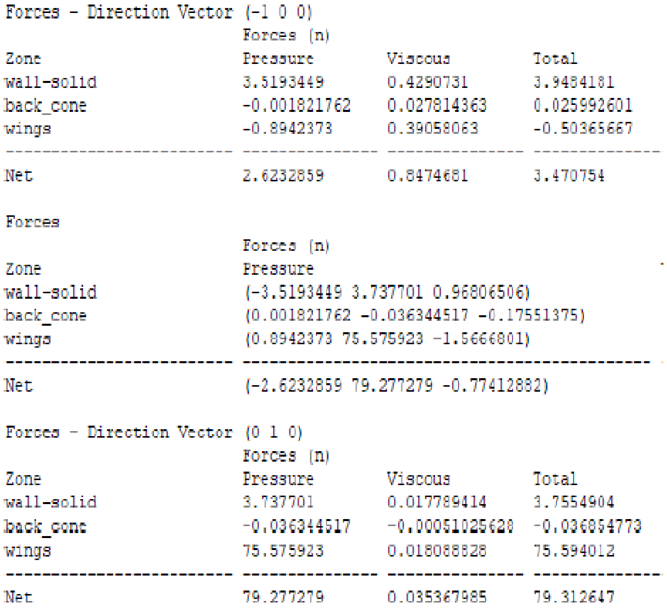
Solver type	Pressure based
Turbulent model	K-epsilon
Fluid Material	Air Density=1.225 kg/m^3
Boundary conditions	Inlet Velocity V_x=13.36m/s V_y=3.58m/s. Outlet Pressure Gauge pressure=0Pa Stationary wall and no slip
Reference value	Computed from Inlet Reference zone Solid
Method	Pressure-viscosity couple scheme-coupled SpatialDiscretization Pressure -Presto

Coarse Meshing



Defaults	
Sizing	
Size Function	Curvature
Relevance Center	Coarse
Max Face Size	Default (717.560 mm)
Mesh Defeaturing	Yes
Defeature Size	Default (3.58780 mm)
Transition	Slow
Growth Rate	Default (1.20)
Span Angle Center	Fine
Min Size	Default (7.17560 mm)
Max Tet Size	Default (1435.10 mm)
Curvature Normal Angle	Default (18.0 °)
Bounding Box Diagonal	14396 mm
Minimum Edge Length	9.5946e-002 mm
Quality	
Inflation	
Assembly Meshing	
Advanced	
Statistics	
Nodes	55196
Elements	302110

Fig. 9: Mesh for 2m span with volume control



```
Forces - Direction Vector (-1 0 0)
                          Forces (n)
Zone                      Pressure        Viscous         Total
wall-solid                3.5193449       0.4290731       3.9484181
back_cone                 -0.001821762    0.027814363     0.025992601
wings                     -0.8942373      0.39058063      -0.50365667
------------------------- --------------- --------------- --------------
Net                       2.6232859       0.8474681       3.470754

Forces
                          Forces (n)
Zone                      Pressure
wall-solid                (-3.5193449 3.737701 0.96806506)
back_cone                 (0.001821762 -0.036344517 -0.17551375)
wings                     (0.8942373 75.575923 -1.5666801)
------------------------- ---------------------------------------------
Net                       (-2.6232859 79.277279 -0.77412882)

Forces - Direction Vector (0 1 0)
                          Forces (n)
Zone                      Pressure        Viscous         Total
wall-solid                3.737701        0.017789414     3.7554904
back_cone                 -0.036344517    -0.00051025628  -0.036854773
wings                     75.575923       0.018088828     75.594012
------------------------- --------------- --------------- --------------
Net                       79.277279       0.035367985     79.312647
```

Fig. 10: Forces along x and y direction for 2m span wing

CALCULATIONS FOR 2m

For half plane

Drag = Fx*cos(α) + Fy*sin(α) ……………….…(1)

= 3.4447*cos(15)+80.036*sin(15)

= 24.044 N

For full plane

Drag = 2*23.985 N

= 48.088 N

CALCULATIONS FOR 2.5 m

For half plane

Drag = Fx*cos(α)+Fy*sin(α) ………………...(2)

= 1.7375*cos(15)+82.572*sin(15)

= 23.0495N

For full plane

Drag = 2*23.985 N

= 46.099 N

CALCULATIONS FOR 3m

For half plane

Drag = Fx*cos(α)+Fy*sin(α)………………….(3)

= 0.3244*cos(15)+82.3876*sin(15)

= 21.6268N

For full plane

Drag = 22*23.985

= 43.2736 N

CALCULATION FORTHRUSTREQUIRED FOR 3m

For steady accelerated climb

Equation along flight path is

M*(dv/dt) = T - D - W*sin(α)……………….(4)

Thrust required is calculated as

T = D + W*sin(α)+M*(dv/dt)

$= 43.2736+17*9.81*\sin(15)+17*\frac{1}{2}$

T = 94.86 N

Table 4: Result of increasing wing span

Span (m)	**Velocity (m/s)**	**Stall Angle (θ)**	**Mass (kg)**	**Drag (N)**	**Acceleration of climb (m^2/s)**	**Thrust required (N)**	**Acceleration of climb (m^2/s)**	**Thrust required (N)**
2	13.836	15	17	47.97	1	108.089	0.5	99.58
2.5	12.22	15	17	46.099	1	106.218	0.5	97.718
3	10.923	15	17	43.273	1	103.393	0.5	94.86

Further increase in wing span will affects the UAV by increasing the gross weight also reducing the payload carrying capacity. Hence the wing span is restricted to 3m.

4. Conclusions

1. After obtaining results from CFD analysis, the pressure distribution on back cone is very less. Hence, the center region of back cone is removed and taped with normal plaster, reducing weight from 230grams to 170grams, reducing 60grams. Totally a gross amount of 530grams has been reduced from the UAV.
2. Because of the increasing the wing span, lift produced by the wing is increased and it leads to UAV flying in lower speed with low thrust which increases endurance by 18.77% than its prior form.

5. Refernce

1. Raees fida swati , Dr.Abid ali khan “Design and Structural Analysis of Weight Optimized Main Landing Gear for UAV Under Impact Loading” journal of space technology vol-4, no-1, july 2014.
2. S.Chaithanya , K.V.N.S. Rama Krishna “Strength Optimization of Landing Gear’s leg for Aerial Vehicle Using ANSYS Solver”, international journal and magazine of engg, technology, management and research, vol-3 2016.
3. Kuldip Ganorkar, Prof. Vishal Deshbharata “design optimization of landing gear of an aircraft”. CAD-CAM Engineering Department, Vidarbha Institute of Technology Nagpur University, India.
4. P. van Ginneken “development of an optimization framework for landing gear design” Delft University of Technology, to be defended public lyon Thursday February18,2016.
5. Manoj Susarla, S.Harshavardhan. “Structural Analysis of the Drag Strut and Dynamic analysis of Aircraft Landing Gear”.

6. Khanh-Hung Nguyen, Yong-Bin Park “Structural Analysis of a Composite Target-drone”, International Journal of Aeronautical & Space Science 2011.
7. S.Prakash, J.Alexander “optimization of design of UAV wing” Apr 24 2014.
8. AmitGoyal “Light Aircraft Main Landing Gear Design and Development”, SAS Tech journals pp. 4550, 2002.
9. T. H. G. Megson, Aircraft structures for engineering students (Elsevier, 2012).
10. E. F. Bruhn, R. Bollard, et al., Analysis and design of flight vehicle structures (Jacobs, 1973).
11. C. Niu, Airframe structural design: practical design information and data on aircraft structures (Conmilit Press, 1988).
12. John D Anderson “Aircraft Performance And Design”
13. Solver Settings from Introductory Fluent Training by Fluent User Services Center.
14. Thrust Calculations Ecalc By McCormick Methods.
15. Araldite casting systems from http://www.electrical-insuation-materials.com.
16. Krishna K & Chawla “Composite materials Science and Engineering” 3rd edition.

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