Effect of Aero Elastic Wing in Aerobatic Unmanned Arial Vehicle

Prof. N. Vivek Masthiraj[1]
Assistant Professor
Department of Aeronautical Engineering,
Sri Ramakrishna Engineering College, Coimbatore, India.

Prof. C. J. Thomas Renald
Associate Professor
Department of Aeronautical Engineering,
Sri Ramakrishna Engineering College, Coimbatore, India.

Prof. V. Selvan
Associate Professor
Department of Aeronautical Engineering,
Sri Ramakrishna Engineering College,
Coimbatore, India.

Abstract- **Active Aero elastic Wing technology represents a new design approach for aircraft wing structures. The technology uses static aero elastic deformations as a net benefit during manoeuvrings. Aero elastic wing is an upcoming technology in wing design. Hence transition to future systems will require educating designers in multiple disciplines of this new design approach. Aero elasticity was often seen as a problem in the past that had to be eliminated when designing an aircraft. Recent research however has been focused on Active Aero elastic wing technology, which integrates aerodynamics, active controls and structural aero elastic behaviour to maximize air vehicle performance. The most innovative concept is the Active Aero elastic wing technology, which induces wing twist in order to increase the aerodynamic performance of the air vehicle..The co-efficient of lift and roll rate of both, normal rectangular wing and aero elastic wing were calculated to show the manoeuvring performance of both wings.**

I. INTRODUCTION

Aero elasticity is mainly the concern of the interaction of flexible structures with the surrounding airflow. It is defined as the mutual interaction of aerodynamic (A), elastic (E) and inertial (I) forces, as demonstrated by the classic Collar‘s Aero elastic Triangle shown in Figure 1. As an aircraft moves through the air, loads act on the structure and cause deformations of the flexible structure. These deformations will change the geometry of the structure which leads to a change in the flow and aerodynamic loads, resulting in a loop of loads and deformations. In most cases the aerodynamic loads and the internal elastic loads in the structure will converge to equilibrium. However, there are cases when the loop becomes unstable, causing increasing deformations leading to structural failure of the aircraft. Aero elastic phenomena fall into two major categories;

a. Static – involves interactions between aerodynamic and elastic forces, such as control surface efficiency at high airspeeds. As a control surface such as an aileron is deflected, the lift is increased. At the same time, due to the lift produced in the trailing edge region the wing experiences a nose down pitching moment. This pitching moment twists the whole wing, reducing the wing angle of attack and causing negative lift. Depending on the wing stiffness and geometry, there is a certain airspeed called the reversal speed, where the positive lift of the control surface deflection is compensated by negative lift due to wing twist, making any control input on the control surface ineffective.

b. Dynamic – involves interactions between inertial, aerodynamic and elastic forces, such as flutter. Flutter occurs when the unsteady aerodynamics cause forces that tend to increase the total energy involved in the motion of the structure and the surrounding airflow. It can also be described as a fluid-structure interaction with negative damping, leading to oscillations with a magnitude increasing with time. All aircraft structures will suffer from flutter at some airspeed. The main challenge for engineers is to tailor the structures to ensure the flutter speed does not lie within the flight envelope for a given aircraft. Other forms of aero elastic phenomenon are dynamic response and vibration. If the aircraft flutter speed is not within at least 1.15Vdiv then the damping of the fluid-structure interaction may be very low, causing the structure to be very sensitive to gusts, landing, sudden control motions, moving shock waves, or other dynamic loads.

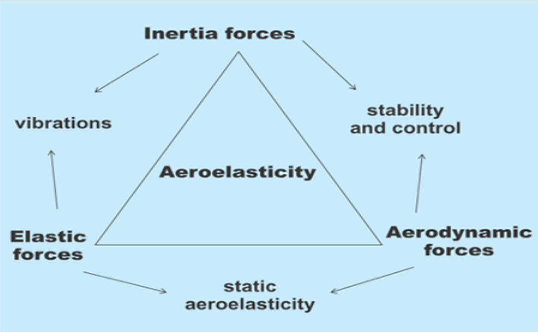

Fig. 1 Collar's aero elastic Triangle

II. UAV SPECIFICATIONS

1. Weight of the UAV, w = 1.47 Kg
2. Wing Span, b = 1m
3. Fuselage length = 0.94m
4. Wing chord, c = 0.2m
5. Wing area, s = 0.2m2
6. Airfoil used = S9000
7. Stall speed,VS = 10 m/s
8. Manoeuvring speed, VA = 20 m/s
9. Cruise speed, Vc = 58 m/s
10. Maximum Aileron deflection, δa = 10 deg
11. Electronic speed controller =40-45AESC

III. ADVANTAGES

The following are the advantages of using aero elastic wing instead of normal rectangular wing in UAV.

1. Integrated aerodynamics.
2. Integrated structural aero elastic behaviour.
3. Maximization of air vehicle

IV. XFLR ANALYSIS OF BOTH WINGS

XFLR5

XFLR5 is an analysis tool for airfoils, wings and planes operating at low Reynolds Numbers. It includes:
X Foil's Direct and Inverse analysis capabilities

Wing design and analysis could be based on Lifting Line Theory, Vortex Lattice Method, and 3D Panel Method

In this paper Vortex lattice method is adopted to carry out the analysis. Figures 2&3 show the analysis results of normal rectangular wing and aero elastic wing. By using this software the aerodynamics parameters such as Co-efficient of Lift (CL), Co-efficient of Drag (CD) and Co-efficient of Moment (CM) were tabulated in Table 1&2. Figure 4 show the effect of aero elastic wing on Lift.

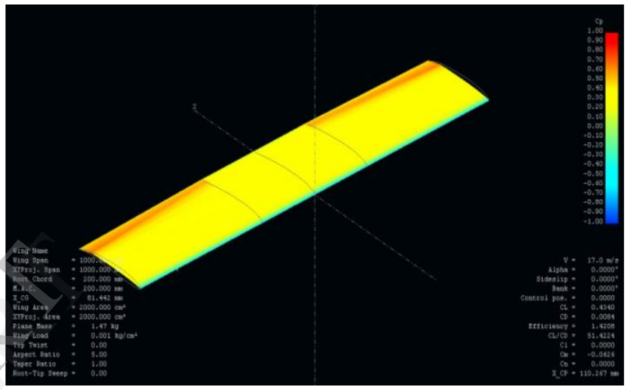

Fig. 2 Result For Normal Wing with Ten Degree Flap Deflection

TABLE I

Results for normal rectangular wing

Flap angle (in deg.)	CL	CD	CM
0	0.2336	0.0027	-0.0405
1	0.2346	0.0029	-0.0405
2	0.2649	0.0033	-0.0429
3	0.2862	0.0038	-0.0454
4	0.3075	0.0043	-0.0479
5	0.3287	0.0049	-0.0503
6	0.3499	0.0055	-0.0528
7	0.3710	0.0062	-0.0552
8	0.3920	0.0069	-0.0577
9	0.4131	0.0076	-0.0601
10	0.4340	0.0084	-0.0626

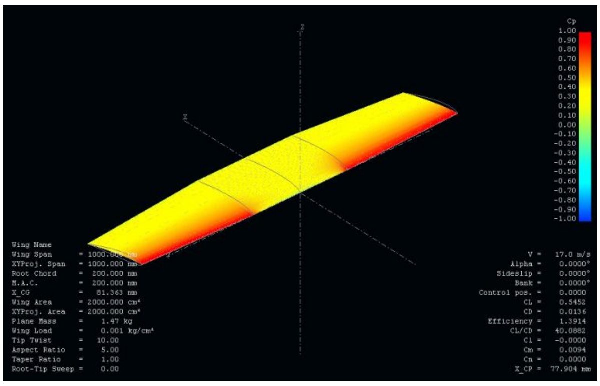

Fig. 3.Result for Aero elastic Wing with Ten Degree Twist

TABLE II
RESULTS FOR AERO ELASTIC WING

Tip Twist (in degrees)	C_L	C_D	C_M
0	0.2336	0.0027	-0.0405
1	0.2652	0.0034	-0.0354
2	0.2968	0.0042	-0.0304
3	0.3284	0.0050	-0.0253
4	0.3598	0.0060	-0.0202
5	0.3911	0.0071	-0.0152
6	0.4224	0.0082	-0.0102
7	0.4534	0.0094	-0.0052
8	0.4842	0.0107	-0.0003
9	0.5148	0.0121	0.0046
10	0.5452	0.0136	0.0094

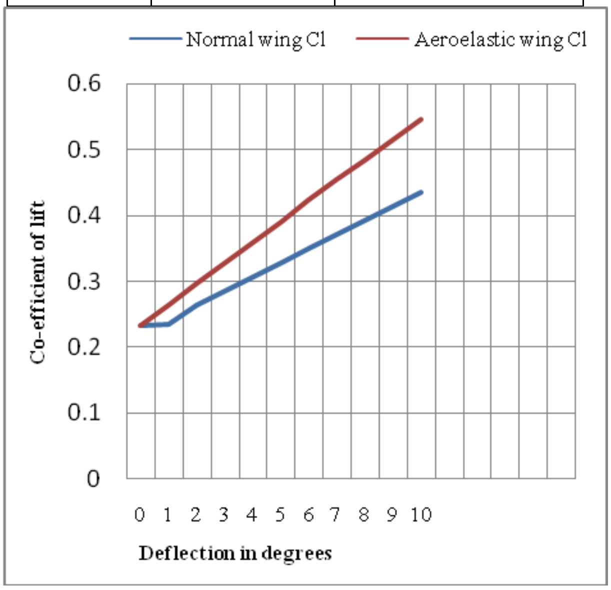

Fig. 4.Effect of Aero elastic wing on Lift

V. RESULTS AND CONCLUSIONS

The primary aim of this project was to design an Aero elastic Wing structure applicable to a lightweight UAV. Therefore the study focused on an optimal design of an Active aero elastic wing structure. From the study of existing rectangular and current design of an aero elastic wing structure, the following conclusions can be drawn.

1. Both Normal and Aero elastic wing aerodynamic parameters were analyzed in XFLR 5.From the comparison of the Aero elastic wing and normal wing, it was seen that the aerodynamic efficiency figures for Aero elastic wing were higher and the co-efficient of lift for the same amount of deflection. This is illustrated in Figure 4.

2. From the roll rate calculation an aero elastic wing proved better efficiency in manoeuvring performance. The Aero elastic wing gave an increased roll rate than the normal wing.

Therefore the proposed aero elastic wing structure can be applied to wing structures of small scale aircraft such as UAVs, Missiles.

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APPENDIX A

Roll Rate is found using the formula: (from Pro Advice 3 AILERON SIZING Copyright ©2011 Great Owl Publishing 1)

$$\frac{pb}{2V} = \frac{-C_{L}\delta a}{C_{lp}} \times \delta a$$

Where,

p - Roll rate in degree per second for full aileron deflection

b - Wing span in meter

$C_L \delta a$ - Roll authority in per degree

C_{lp} - Roll damping in per degree

δa - Aileron deflection angle in degrees

V - Airspeed in m/s

For Normal Rectangular Wing:

b = 1 m

VA = 20m/s

CLδa = 9.8735×10-3 per degree

Clp = -0.02547 per degree

δa = 10 deg

CLδa = Clδa (b22-b12)/b2 = 9.873510-3/deg

Coefficient of lift at maximum aileron deflection, Clδa = CL/δa

= 0.4340/10

= 0.04340/deg

C_{lp} = - [Clα+Cd0/6] = -0.02547/deg

Clα or a = Lift curve slope = a0/ [(1+57.3a0)/πeA]

= 0.0725 /deg

a0 = ΣαCL/ Σα2=6.739×10-3 / deg

e = Span effectiveness (Oswald factor 0.95)

A = Aspect ratio = Span2/Area = 12/0.2 = 5

Cd0 = Section drag coefficient = 0.010

For Aero Elastic Wing:

b = 1 m

V = 17 m/s

CLδa = 0.01240 per degree

Clp = -0.02953 per degree

δa = 10deg

CLδa = Clδa (b22-b12)/b2 = 0.01240 /deg

Coefficient of lift at maximum aileron deflection, Clδa = CL/δa

= 0.5452/10

= 0.05452/deg

C_{lp} = - [Clα+Cd0/6] = -0.02953 /deg

Clα or a = Lift curve slope = a0 / [(1+57.3a0)/πeA]

=0.08335 /degree

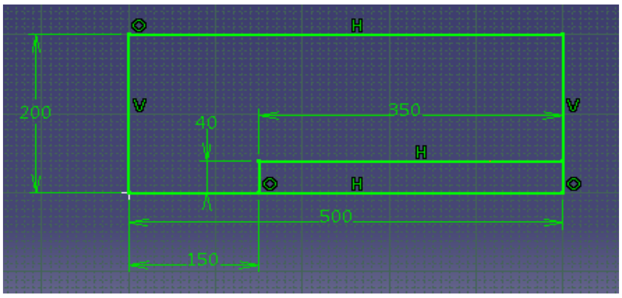
a0 = ΣαCL/ Σα2=8.2154×10-3 / deg

e = Span effectiveness (Oswald factor 0.95)

A = Aspect ratio = Span2/Area = 12/0.2 = 5

Cd0 = Section drag coefficient = 0.010

Dimensions of half wing:



b1= 0.15m, b2 = 0.5m, b = 1m