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Design and Analysis of Wing for Next Generation UAV’s

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Abstract— **A morphable /adaptive wing is the one that can change its geometry to accommodate multiple flight regimes. In this paper, we propose mechanisms to continuously morph a wing from a lower aspect ratio to a higher aspect ratio and to further extremities of a gull configuration. The morphable wing’s two-link structure is telescopic in nature. The telescopic actuation is performed by a linear actuator consisting of a rack and pinion arrangement. The cross-sectional area remains almost constant but the aspect ratio does change due to the telescopic action. The 3D-CAD model developed in CATIA V5 and is imported into ANSYS 14.5 Work bench. The detailed structural analysis of the complete wing will be obtained by using ANSYS Work bench.A variable aspect ratio wing would try to incorporate the high speed and maneuverability benefits of low aspect ratio wings, and increased range and fuel efficiency from the large aspect ratio wings.This type of wing system is to improve the range of achievable flying conditions for an unmanned aerial vehicle (UAV).**

Keywords* — *Biological Mimicry, Morphing, CATIA, ANSYS.

I. INTRODUCTION

A morphable/adaptive wing is the one that can changes its geometry to accommodate multiple flight regimes. The ideal use of an adaptive strategy allows the wing to vary its geometric parameters in flight during encounters in situ of changing flow conditions such as wind speed or direction. Serious efforts to master the air were initially taken by Leonardo da Vinci towards the end of the 1400s. He systematically studied bird and bat wings and observed their flight. Based on these observations, he first tried to build a man-powered flapping machine. But the first aviation trails were made by Otto Lilienthal in late 1800’s. He studied the gliding flight in birds and based on these observations constructed gliding planes similar to today’s hand-gliders. Lilienthal was the first to realize the importance of a carefully shaped wing section; he found that the camber and an appropriate thickness of the airfoil improved aerodynamic performance, as compared to a flat plate[1].

In camber change, the adaptive airfoil can change camber to obtain a desired lift thus eliminating the need for conventional control surfaces[2]. In morphing via a differential twist wing, the wing is configured to optimize the twist angle to obtain lowdrag and high-lift aerodynamic characteristics. The wing sweep change is designed to change the wing configurations to suit the various flight conditions[3]. A variable aspect ratio wing would try to incorporate the high speed and maneuverability benefits of low aspect ratio wings, and increased range and fuel efficiency from the large aspect ratio ones. The adaptive morphing using smart materials investigates the aerodynamic conditions by modifying the boundary layer characteristics of the fluid flow over the wings[4].

II. METHODOLOGY

The birds employ an adaptive wing technology to suit their varying aerodynamic needs. By adaptive wing technology, we indicate their change in the wing shape as well as the aspect ratio. The idea here is to develop an aircraft wing using this biological motivation from birds to re-optimize the flight performance to suit the varied aerodynamic conditions experienced in multi-task mission.

S. No	Wing Type	Characteristics
1.	**Short, broad**, cupped wings	**Rapid takeoff** and short-distance flight
2.	Shorter and broader wings with slotted primary feathers	Soaring flight
3.	Flat moderately long, narrow, triangular wings	High-speed flight
4.	Large, distinctly arched wings	Flapping flight
5.	**Long, narrow, flat** pointed wings	**Gliding** flight
6.	Pointed, swept-back wings	Hovering or motionless flight

Table - 1 Bird wing types and flight characteristics

To summarize, the above Table 3.1, discusses the bird wing shapes and their flight characteristics. The table shows a variety of morphing techniques employed by the bird wings to accomplish dynamic maneuvering and stabilization. The highlighted wing types correspond to the various flight phases that a typical combat vehicle is subjected to. Rapid take-off, soaring at high altitudes, steep-descend flight, slow low level flying conditions and, short and sudden landing are the conditions aimed to be emulated via a single morphable wing.

Deriving inspiration from the seagull wings two-limb structure follows the design and development of a simple two-link mechanism:

- Shorter and broader wings for rapid takeoff and short-distance flight,
- Moderately long (and thus comparatively narrower) wings for gliding-flight, and
- Gull wing configuration for shortest distance in landing.

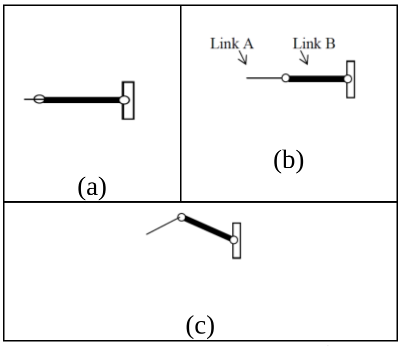

Figure - 1 Preliminary Mechanism Configurations

III. DESIGN OF WING

The design of the wing is performed after a lot of preliminary calculations using ANSYS and the design was give some appropriate values and was modeled using CATIA software. We modeled three configurations of the wing i.e., Un-extended wing, Extended wing, Gull wing for the structural analysis. The wing span is decided after discussing a lot with some of the aero-modelers, and the chord length is calculated based on the best wing area that can provide good lift and is less in weight. The Final wing span for different configurations are given in table 4.1

Wing configuration	Span
	Inches
Unextended wing span	40
Extended wing span	60
Gull Wing span	51.96
Chord length of main wing	9
Chord length of extendable wing	7.5

Table - 2 Wing configuration

Design-foil is one of the software's which are used to create desired airfoil sections. A thicker profile of NACA 0018 was chosen to incorporate the mechanism inside the wing with a maximum height of the elliptical cross-section of 1.62 inches.

The airfoil can be imported to CATIA, which is a in-built operation in "Design-foil."

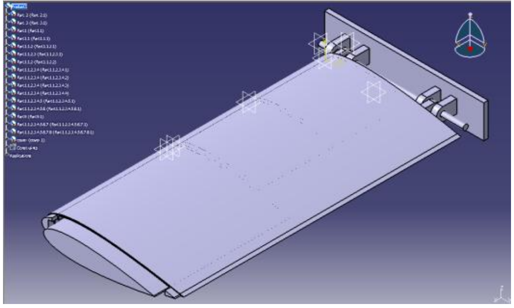

Figure - 2 Un-extended wing structure

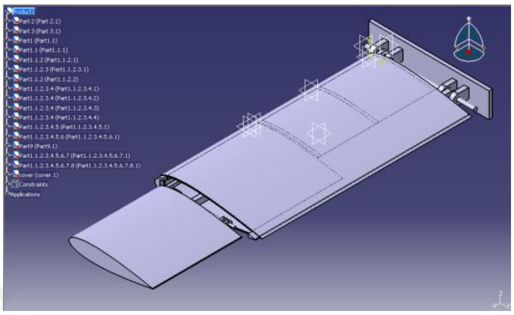

Figure - 3 Extended wing structure

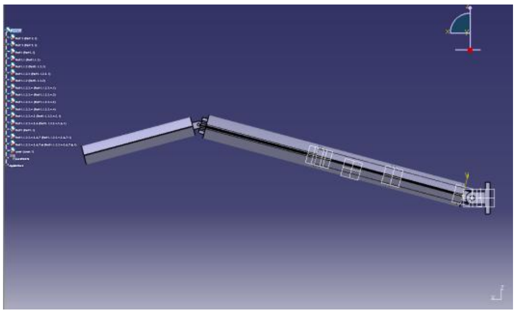

Figure - 4 Gull wing model

IV. ANALYSIS

A. *Material Selection*

Further, the material is chosen to be Balsa Wood (except for spars and rack-base) because of its relatively low cost and other good characteristics. Table 4.2 summarizes the mechanical properties of the materials used.

Material →	Balsa wood (High density)	Balsa wood (Low density)	Structural Steel	Aluminium Alloy
Property				
Density (kg/m^3)	224.21	74.736	2770	7850
Young's modulus (Pa)	5.309E+08	3.8886E+08	7.1E+10	2E+11
Poisons ratio	0.23	0.23	0.33	0.3

Table - 3 material properties of materials used in the analysis

B. *Detailed structural analysis*

The 3D models, created in CATIA V5 R20, were being modified continuously to meet the design requirements. This model is then imported through IGES format to ANSYS workbench for further detailed structural analysis.

C. *Results*

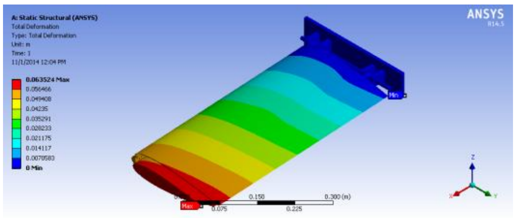

Figure - 6 total deformation on unextended wing

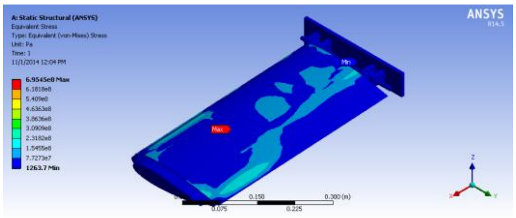

Figure – 7 Vonmises stress on unextended wing

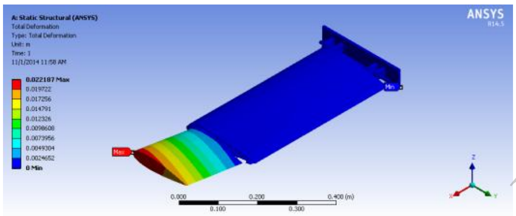

Figure - 8 Total deformation of extended wing

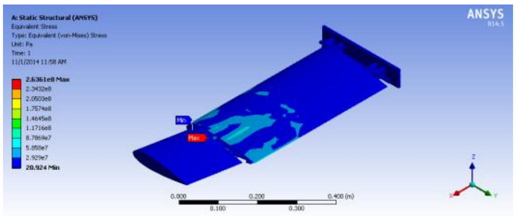

Figure - 9 Von-mises stress of extended wing

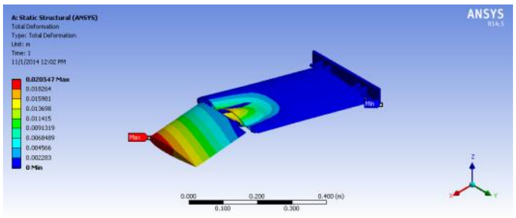

Figure - 10 Total deformation of gull wing

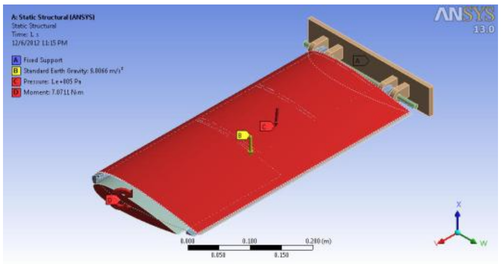

Figure - 5 Applied boundary conditions

All the configurations of the wing are tested in a similar setup as shown in fig. 5.1. The deformations and stresses are plotted in ANSYS workbench.

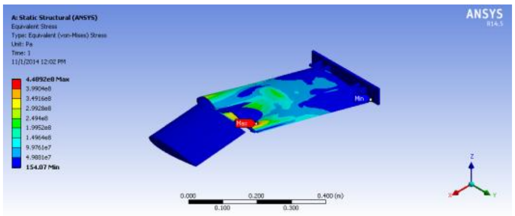

Figure – 11 Von-mises of gull wing

The results states that the designed wing is perfectly working in normal condition and it needs a little structural strengthening in other two cases.

V. CONCLUSION

Based on the results that we got we came to a conclusion that, when the pressure loads are applied, the skin of the wing is experiencing high stresses causing high deformation, this can be reduced either by reducing the inter-rib spacing in the main wing structure or by attaching more stiffeners to skin wing structure. After looking the results of extended and gull wing configuration, we can say that maximum stresses are occurring on the two rods, one which is connecting the rack-base to the extendable wing and the other which is connecting the main wing to the fuselage. These values will differ from the actual value because in the actual model we will be having the connections from the servo motors, mounted on the platform of the rack-base, which are used for morphing of the wing into extendable and gull wing configurations.

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