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# Investigation on Four Distinct Wing Configuration Using Morphing Technology

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***Abstract*:- Aircraft wings are a compromise that allows an aircraft to fly at a range of flight conditions, but the performance at each condition is sub-optimal. The ability of a wing configuration to change its geometry during flight has interested researchers and designers over the years as this reduces the design compromises required. Morphing aircraft wings face conflicting design requirements of flexibility to accomplish the desired shape change, and stiffness to withstand aerodynamic loads. It is a promising enabling technology for the future next-generation aircraft even while morphing solutions always led to penalties in terms of cost, complexity, or weight, although in certain circumstances, these can be overcome by smart materials. Aerodynamic performance and stability should be considered in the context of the wing's structural integrity and aero elasticity. Attention should be paid to the unsteady nature of the flow, as standard quasi-steady flow analysis techniques should be abandoned due to the rapid changes in wing shape and motion. Due to the large number of variable and measured parameters, an advanced control system is required to relate the flight conditions with changes in geometry. The challenge is to design a wing structure that can withstand the prescribed loads, but is also able to change its shape while maneuvering. Implementing the four-distinct wing structure such as anhedral, dihedral, swept forward and swept backward seems to be a unique objective of our work. It was analyzed and determined that the stress and deformation lie within the limit. Usage of control system being a huge challenge and since it increases the weight of the aircraft, a crescent wing model is being suggested which could be a suitable configuration for such morphing wing technology. Though it seems to lie on a complexity way, the combination of all distinct wing structure featured in a single wing shows the advantage pack of this adaptable morphing wing structure.***

***Keywords:- Wing Configuration Wing Morphing Quasi-Steady Flow Maneuvering Swept Wings Cresent Wing***

## INTRODUCTION

Here introduces the paper, and put a nomenclature if necessary, in a box with the same font size as the rest of the paper. The paragraphs continue from here and are only separated by headings, subheadings, images and formulae. The section headings are arranged by numbers, bold and 9.5 pt. Here follows further instructions for authors.

### *1.1 Survey*

The observation of flight in nature has motivated the human desire to fly, and ultimately the development of aircraft. The designs of the first flying machines were relatively crude and even today nature has much to teach us and continuously inspires research. By directly comparing aircraft with nature, designers seek inspiration, to achieve the simplicity, elegance, and efficiency that characterize animal species obtained by thousands of years of biological evolution. The attraction for designers is the integration between the structure and function that characterizes the wings of birds (Bowman et al., 2002). Even in complex urban environments, birds can rapidly change shape to transition from efficient cruise to aggressive maneuvering and precision descents. Avian morphology permits a wide range of wing configurations, each of which may be used for a flight task (Abdul Rahim and Lind, 2006).

The idea of changing the wing shape or geometry is far from new. The Wright Flyer, the first heavier than air aircraft with an engine, enabled roll control by changing the twist of its wing using cables actuated directly by the pilot. The increasing demand for higher cruise speeds and payloads led to more rigid aircraft structures that are unable to adapt to different aerodynamic conditions, characterizing a typical mission profile. The deployment of conventional flaps or slats on a commercial airplane changes the geometry of its wings. The wings are designed as a compromise geometry that allows the aircraft to fly at a range of flight conditions, but the performance at each condition is often sub-optimal. Moreover, these examples of geometry changes are limited, with narrow benefits compared with those that could be obtained from a wing that is inherently deformable and adaptable. The ability of a wing surface to change its geometry during flight has interested researchers and designers over the years: an adaptive wing diminishes the compromises required to insure the operation of the airplane in multiple flight conditions (Stanewsky, 2001).

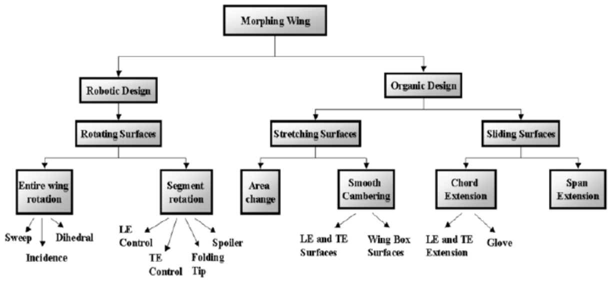
Despite the apparent complexity of variable-geometry aircraft, nature has evolved thousands of flying insects and birds that routinely perform difficult missions. Observations by experimental biologists reveal that birds such as falcons can loiter on-station in a high-aspect ratio configuration using air currents and thermals until they detect their prey. Upon detection, the bird morphs into a strike configuration to swoop down on an unsuspecting prey.

### *1.2. Morphing*

Morphing is short for metamorphose and, in the aeronautical field, is adopted to define 'a set of technologies that increase a vehicle's performance by manipulating certain characteristics to better match the vehicle state to the environment and task at hand' (Weisshaar, 2006). Using this definition, established technologies such as flaps or retractable landing gear would be considered morphing technologies. However, morphing carries the connotation of radical shape changes or shape changes only possible with near-term or futuristic technologies. There is neither an exact definition nor an agreement between the researchers about the type or the extent of the geometrical changes necessary to qualify an aircraft for the title 'shape morphing.

### *1.3. Classification of Morphing Technologies*

This classification is useful in that different current morphing efforts fallinto one or the other of these categories.



### *1.4. Limitations of using Morphing Technology*

In recent times morphing technology has triggered a lot of interest among the scientists, which obviously made them to work more on this technology. Though morphing wing plays a major role in aviation industries, it has its own limitations. For an aircraft, continuous morphing wing surfaces have the capability to improve efficiency in multiple flight regimes. However, material limitations and excessive complexity have generally prevented morphing concepts from being practical. Thus, the goal of the present work was to design a simple morphing system capable of being scaled to UAV or full-scale aircraft. The material selection and the actuation system used for blending the wings plays the significant role meanwhile it's very difficult to choose a wise option among the available. Recent advances in smart materials research, including developments in actuation technology, constitutive laws and modeling, optimization and control, and failure prediction, demand more purposeful steps to progress variable-geometry small aircraft. The blending of morphing and smart structures (defined as structures capable of sensing the external environment, processing the information and reacting accordingly) seems mandatory to enable innovative solutions to be realizable and competitive with traditional designs, and overcome the penalties associated with current morphing applications. This integrated approach requires multi-disciplinary thinking from the early stages of development, which significantly increases the overall complexity even of the preliminary design. Design interactions are more problematic with morphing vehicles.

### *1.5. Airfoil*

To choose the apt aerofoil for designing the wing, a two-different aerofoil is chosen. The aerofoils are of NACA series 0009 and NACA 2412

## 2. MORPHING WING DESIGN

### *2.1. Airfoil Design*

For the betterment of the apt design NACA 2412 airfoil is chosen and the following dimensions are given for it project.

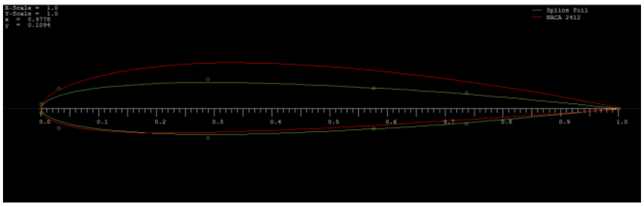


Fig2.1 NACA2412 Airfoil

Fig2.2 Graph indicating CL, CD, Cm and ratio of CL /CD NACA2412

**Dimension:**

Wing span = 1000mm
Root chord = 300mm
Tip chord = 300mm
Wing area = 0.3m2

The airfoil coordinates of NACA2412 is imported into workbench and the airfoil is projected. With the above given dimensions, the airfoil is designed aptly and accordingly.

### *2.2. Ribs Design*

The ribs are very similar to that of the airfoil shape. Four ribs are being generated in between the wing structure. Each spacing 96mm between them and stretched to a thickness of about 20mm.Notably I section beam is used to design the ribs for its high torsional stability.

Dimension:
Length = 500mm
Ribs Spacing = 96mm
Thickness = 20mm

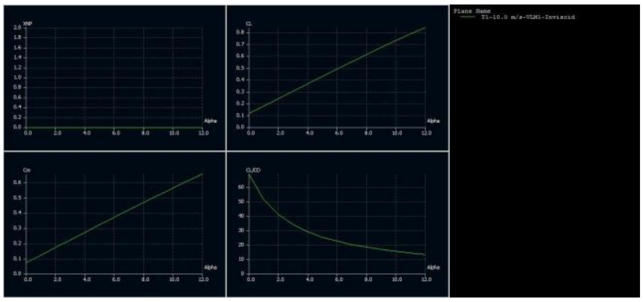


Fig 2.1 Design of Rib

### *2.3. Spar Design*

Most commonly used beam for spar design is I-beam for their torsional stability. But in our work, the spar is to be pin jointed at each rib. So rectangular cross section spar is being used.

**Dimension:**
Length= 243.67mm
Chamber radius=7.5mm
Pin joint radius= 6mm

*2.4. Assembled Morphing Design*

With the given specimen dimension, the part modelling are done in CATIA V5 and then the models are been assembled. The following shows the design of a planar morphing wing.

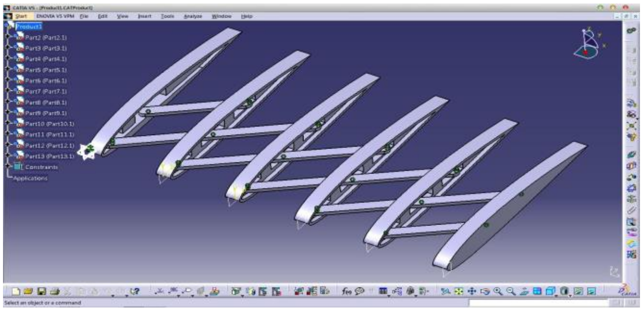
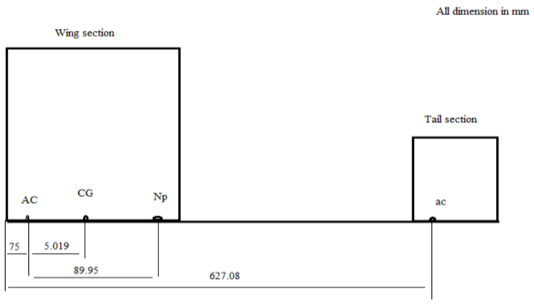


Fig3.3 Planar Morphing Wing

3. MORPHING WING CALCULATION

Aerodynamic center should be at 25% of total length of mean aerodynamic chord
Mean aerodynamic chord= 300mm
Therefore Ac = 0.25*300
Ac = 75mm
P = {L * S(tail)/ 3* S(wing)} - {1/15 [ R^2 + RT+T^2] / [R+T]}
P = {(0.62708*0.05024) /(0.3*0.3)} – {1/15 [0.09+(0.09)+(0.09)}/(.009)
P = 5.019mm
Neutral point = S(tail)/ {S(wing)+S(tail)}
=0.60708*0.05024/(0.380.05024) = 89.95mm
Static margin = Mean aerodynamic chord/10
= 0.3/10
= 0.03m or 30mm
Therefore cg = Aerodynamic center + P
= 75 + 5.019
=80.019mm



Horizontal Tail Specification

In order to design the horizontal tail, NACA 0009 airfoil is been chosen. Its design specification is been calculated below.
Horizontal tail span (SH) = 0.33471m
Horizontal tail area (AH) = 0.05024m2

(a) Aspect ratio = 2/3 * aspect ratio(wing)
= 2/3*3.33
= 2.3
(b) Span(bH)
Aspect ratio = bH 2 / SH
Where SH = 0.05024 m
ThereforebH = 0.33471 m
(c) Chord (CH)
Aspect ratio = bH / CH
Therefore
Chord = CH = 0.14552 m

*4.4.2 Vertical Tail Design*

Even for designing the Vertical tail, NACA 0009 airfoil is been chosen. Merely the horizontal and vertical tail has the same specification. Its design specification is been calculated below.
Vertical tail span (Sh) = 250mm
Vertical tail area (Av) = 0.227 m2

(a) Aspect ratio = 2/3 * aspect ratio(wing)
= 2/3*3.33
= 2.3
(b) Span(bh)
Aspect ratio = bh 2 / Sh
Where Sh = 0.05024 m
Therefore bh = 0.33471 m
(c) Chord (Ch)
Aspect ratio = bh / Ch
Therefore
Chord = Ch = 0.14552 m

4.4.1 XFLR5 SOFTWARE ANALYSIS

*4.1 Planar Wing Analysis*

The planar wing which was generated using Naca2412 aerofoil was tested using the XFLR5 software. For a given input of 10m/s at 0° angle of attack. The coefficient of lift and coefficient of drag obtained was 0.1278 and 0.0015 respectively. Similarly, for different angle of attack the wing was analysed. The results are tabulated.

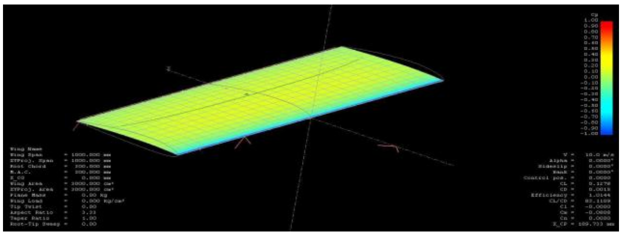


Fig 4.1 XFLR analysis of Planar Wing without tail design

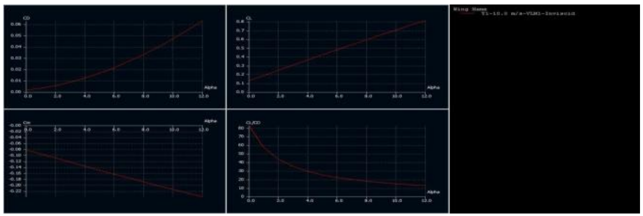
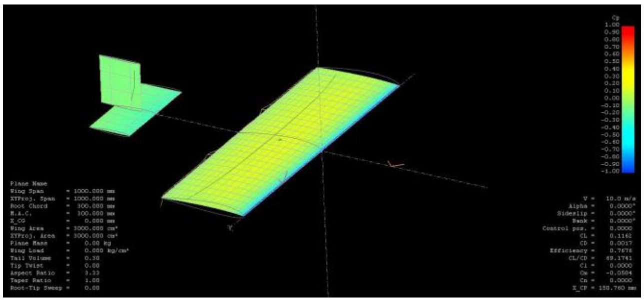


Fig 4.2 Graph indicating CL, CD, Cm and ratio of CL /CD (Without tail)

The planar wing along with tail design which was generated using Naca2412 and Naca0009 aerofoil respectively was tested using the XFLR5 software. For a given input of 10m/s at 0° angle of attack. The coefficient of lift and coefficient of drag obtained was 0.1102 and 0.0017 respectively. Similarly, for different angle of attack the wing was analysed. The results are tabulated.



```
Plane Name
Wing Span        = 1000.000 mm
XYProj. Span     = 1000.000 mm
Root Chord       =  300.000 mm
M.A.C.           =  300.000 mm
X_CG             =    0.000 mm
Wing Area        = 3000.000 cm²
XYProj. Area     = 3000.000 cm²
Plane Mass       =    0.00 kg
Wing Load        =    0.000 kg/cm²
Tail Volume      =    0.30
Tip Twist        =    0.00
Aspect Ratio     =    3.33
Taper Ratio      =    1.00
Root-Tip Sweep   =    0.00
```

```
          V =   10.0 m/s
      Alpha =   0.0000°
   Sideslip =   0.0000°
       Bank =   0.0000°
Control pos. =   0.0000
         CL =   0.1162
         CD =   0.0017
 Efficiency =   0.7676
      CL/CD =  69.1741
         Cl =   0.0000
         Cm =  -0.0584
         Cn =   0.0000
       X_CP = 150.760 mm
```

Fig 4.3 XFLR analysis of Planar Wing along with tail design

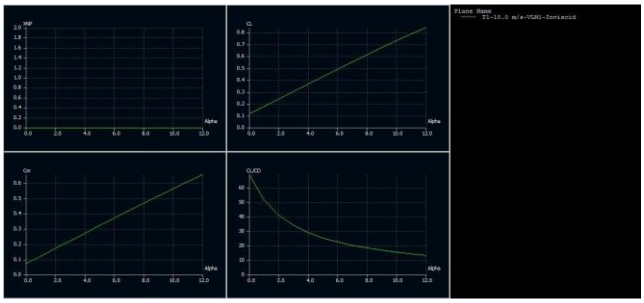


Fig 4.4 Graph indicating CL, CD, Cm and ratio of CL /CD (With tail)

## 5. THEORETICAL CALCULATION

### 5.1 Shear force and Bending Moment

For any wing the maximum load is supposed to act along its spar. Hence here the spar is considered and their shear force and bending moment behaviour is been calculated.

Length of spar = 0.24409m

Load acting = 5.88N

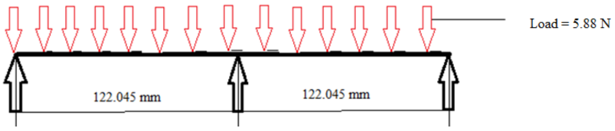


Fig 5.1 Load distribution along the spar

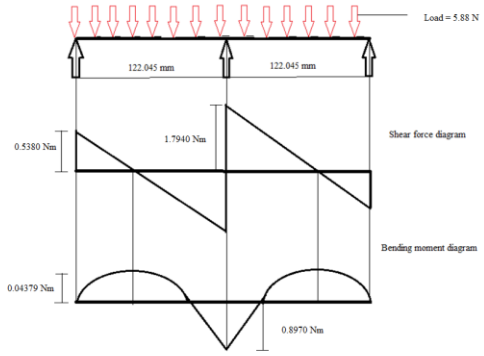


Fig.6.2 Shear Force and Bending Moment diagram

## 6. ANSYS STRUCTURAL ANALYSIS

### *6.1 Material Selection*

It is very common that aerospace industries prefer aluminium and steel component for their special features. Here the analysis is being made using both the materials applied on to the structures.

### *6.2 Stress Analysis*

The structure was analysed where it experienced the minimum stress of 178.15 Pa and the maximum stress of 4.3488*108 Pa, which is merely lesser than the original capacity of the material itself.

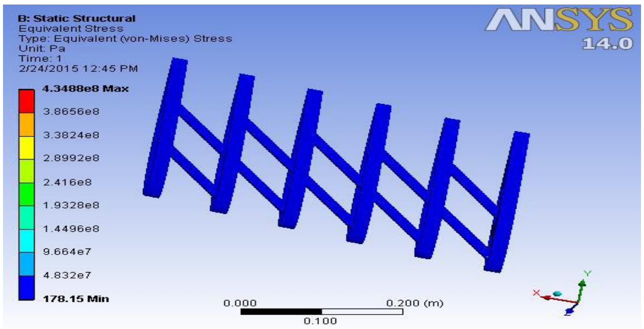


Fig 6.1 Stress analysis of Aluminium material

### *6.3 Stress Analysis*

The Stress analysis was performed on the steel material, in which it was noticed that the stress experienced by the steel material was higher than the aluminium material. A maximum of 4.4718Mpa was encountered.

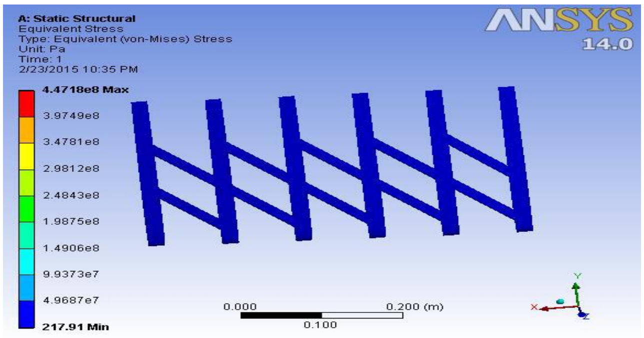


Fig 6.2 Stress analysis of Steel material

### *6.4 Deformation Analysis*

The deformation occurred along the structure was within the limit. A Maximum of 0.0086798m is been experienced by the aluminium structure.

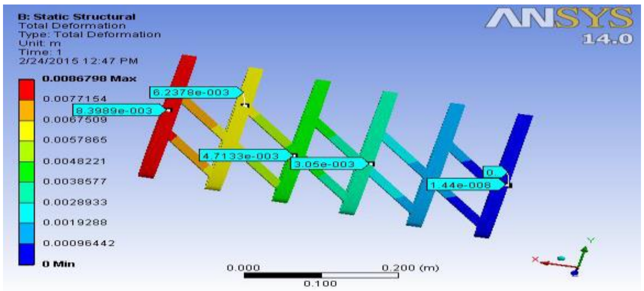


Fig 6.4 Deformation analysis of Aluminium material

### *6.5 Deformation Analysis*

The deformation occurred along the structure was within the limit. A Maximum of 0.0092112m is been experienced by the steel structure which higher than that of aluminium material.

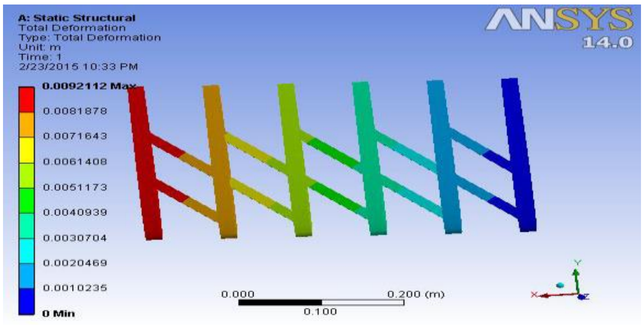


Fig 6.5 Deformation analysis of Steel material

### *6.6 Comparative Results*

From the above table it is very clear that Aluminium material is less exposed to damages rather than that of steel. Hence it is better to opt Aluminium material for designing the structure.

| CONTENT | ALUMINIUM | | STEEL | |
|---|---|---|---|---|
| | MINIMUM | MAXIMUM | MINIMUM | MAXIMUM |
| STRESS | 178.15 Pa | $4.3488*10^8$ Pa | 217.91 Pa | $4.4718*10^8$ Pa |
| STRAIN | $1.607*10^{-9}$ | 0.002549 | $1.7517*10^{-9}$ | 0.002593 |
| DEFORMATION | 0 | 0.00867 m | 0 | 0.0092112 m |

Fig 6.6 Comparative results between Aluminium and Steel material

## CONCLUSION

In this work, a wing shape change is sought wherein the shape change is continuous in nature and the internal mechanism allows the overall shape of the wing to vary. This work addresses two aspects of the wing design, namely the development of an internal structure that fulfils the morphing requirements and the aerodynamic shape that could be suitable while morphing.

The work on morphing wing structure carries the use of conventional wing structure beyond the regular use of it. As said, the morphing wing structure inculcates the four distinct wing configurations which adds several pros to the structure namely the anhedral, dihedral, swept back and swept forward configurations. The calculated results clearly depict the usage of different configurations in challenging environments. Apart from these, the swept back type is preferred for reducing the drag divergence phenomenon of supersonic aircrafts and anhedral, dihedral configurations are widely used for overcoming the challenges during landing and taking-off of carrier aircrafts.

Even though the structure is theoretically found to can withstand the loads, certain practically challenging situations should be faced. One of the major challenges is to fix the fuel tank into the wing. This can be solved by using a type of crescent wing structure having the fuel tank in it. Another major challenging situation is to fix the control surfaces issue. This can be overcome by using the crescent wing model. Such type of wing has larger span area, so that installing the control surfaces will not be a huge problem. However, the design should be in such a way as the control surfaces and the wing should be integrated with each other. A typical example for a crescent wing model is shown below.

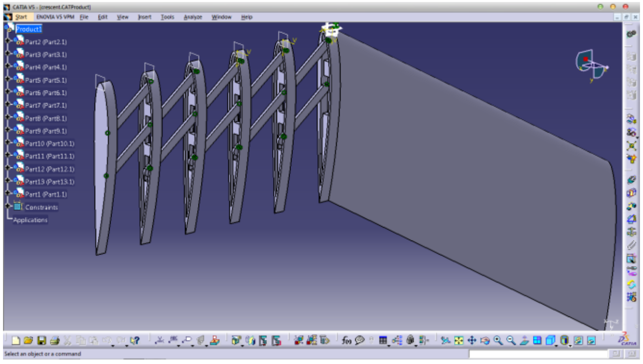


Fig 7.1 Crescent wing model

Fig 7.2 Prototype of the internal structure of morphing wing

### Appendix A. An example appendix

Authors including an appendix section should do so before References section. Multiple appendices should all have headings in the style used above. They will automatically be ordered A, B, C etc.

### A.1. Example of a sub-heading within an appendix

There is also the option to include a subheading within the Appendix if you wish.

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