

# STATIC AND DYNAMIC ANALYSIS FOR A SWEEP BACK DIHEDRAL WING AND ITS OPTIMIZATION

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**Abstract.** For a stable flight, it is required adequate stability of the aircraft to have good conditions of navigability. The wing dihedral angle, the format, the position and the amount of wings are factors affecting the lateral stability of any aircraft (small or large). The purpose of this paper is study the applicability of dihedral wings in aircrafts, simulating the applications in a small aircraft. Thus, through theoretical final analysis, we can observe the use of dihedral angle implies some viability and it is going to bring significant improvement in performance and stability of the aircraft during the flight. The parameters used in this study were based on the project of a cargo radio controlled aircraft designed by Urutau Aero design, Research and Competition team, to the SAE Brazil Aero design Competition in which engineering students must design a robust and light cargo radio controlled aircraft.

**Key words:** aircraft wing using ribs and spars, Static analysis, Modal analysis, random vibration analysis, Buckling analysis, analysis

## 1. Introduction

In flying machine preparatory outline – the second step in configuration process. Three parameters are resolved amid preparatory outline, in particular: air ship greatest departure weight (WTO); motor power (P), or motor push (T); and wing reference zone (Sref). The third step in the plan procedure is the detail outline. Amid detail configuration, real flying machine parts, for example, wing, fuselage, even tail, vertical tail, drive framework, landing rigging and control surfaces are outlined one-by-one. Every air ship part is outlined as an individual substance at this progression, yet in later plan steps, they are incorporated as one framework – flying machine and their associations are considered.

The wing might be considered as the most essential segment of an airplane, since a settled wing air ship is not ready to fly without it. Since the wing geometry and its elements are affecting all other flying machine parts, we start the detail configuration process by wing outline. The essential capacity of the wing is to create adequate lift compel or basically lift (L). In any case, the wing has two different preparations, specifically drag power or drag (D) and nose-down pitching minute (M). While a wing fashioner is hoping to augment the lift, the other two (drag and pitching minute) must be limited. Actually, a wing is considered as a lifting surface that lift is created because of the weight distinction amongst lower and upper surfaces.



## 2. Literature Review

The seeds of winglet (NASA 2004) were first presented by English aerodynamicist F.W Lancaster in the late 1800s. Lancaster protected the idea of winglet said a vertical surface at the wingtip would diminish drag. It was not fruitful until the point when Whitcomb refined it. The need to convey forward the examination on winglet was because of oil emergency in 1970s which requested the prerequisite of enhancing the flying machine productivity.

Whitcomb (1997) did look into at NASA Langley Exploration Focus on the wing tip mounted winglets on KC 135 transport airplane. The setup think about he did showed the actuated drag decreased by 20% and thus the lift to drag proportion expanded to 9% for plan Mach number of 0.78. The range increment of the vehicle flying machine is by 7% at cruising speed. The lift to drag proportion change is more than twice that accomplished by wing-tip expansion. The negative addition in pitching minute because of winglet is less contrasted with wing-tip augmentation. The general execution change of winglet relies upon the occurrence point of upper winglet. The execution change of lower winglet is just peripheral.

## 3. Mythology

This flying machine configuration has basically developed to a payload compartment with wings and a tail, as a customary last plan. The purpose behind this plan is two overlay: Simplicity of development and a consequence of breaking down the scoring capacity of the course. Since we chose to convey tennis balls for our payload, it is crucial that our outline of the payload compartment while being sufficiently vast to house the balls, additionally showed least streamlined elements required finishing a quick lap of the course, while being light. The present outline includes 1.5m traverse, single tractor and high-wing monoplane. The flying machine is required to sit inside the 1.5m x 1.15m stage limits, boosting viewpoint proportion and giving extra length to the fuselage fairing, in this manner amplifying streamlined proficiency. The air ship is relied upon to use froth/carbon-fiber composite development for the wing, tail and fuselage interior structure. The fuselage will have separable high wing, enables simple access to the payload. This payload-centred setup limits the key parameters of framework weight through its basic productivity and access to payloads, while giving adequate streamlined execution and propulsive power thickness.

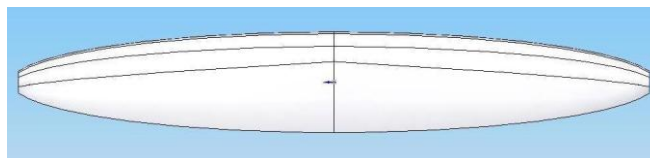
### 3.1 Required Parameters

Keeping in mind the end goal to make a fruitful applied outline, it was resolved that various parameters should have been concluded. The objective of the principal period of configuration was to test these parameters inside existing R/C outlines and afterward go this data through our course prerequisites and transform the parameters.

### 3.2 Wing Plan

There were 3 decisions for the sorts of wing that we could utilize.

#### *Elliptical Wing*



**Figure 1:** Elliptical Wing

The Elliptical wing shows in figure 1 offers various points of interest in that it creates the base prompted drag for a given viewpoint proportion. Furthermore, a circular wing likewise happens to be appropriate for overwhelming payload weights. While the wing is more proficient for L/D, its

slow down attributes is very poor when contrasted with a rectangular wing. The most serious issue was the manufacturability of a curved moulded wing.

#### *Tapered Wing*

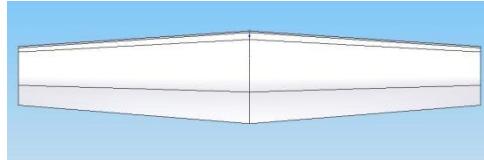


Figure.2: Tapered Wing

The Tapered wing show in figure 2 was a decent choice since it gave us the advantages of a curved wing while as yet being rectangular fit as a fiddle. The decreased wing additionally has included preferences of from the point of view of weight and solidness. The decreased wing was additionally a decent decision from a weight productivity perspective since the measure of material as we leave from the root diminishes.

#### *Rectangular Wing*

The rectangular wing show in figure 3 is the best wing for utilization from a manufacturability perspective. The rectangular wing tends to slow down first at the wing root and gives satisfactory slow down notice, sufficient aileron adequacy, and is normally very steady. It is additionally regularly supported for the outline of ease, low speed R/C planes.

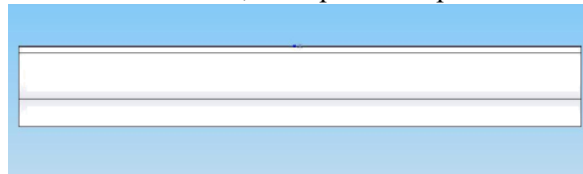


Figure 3: Rectangular Wing

Table 1 is the final products of the exchange ponder for the kind of wing plan. We chose to run with a rectangular wing since it could without much of a stretch beat contending plans in view of components, for example, development and weight execution

Table 1: Wing Sort Score Table

Categories	Weighting	Rectangular	Elliptical	Tapered
Construction	40%	5	2	3
Flight Performance	30%	3	3.5	3
Theoretical Final analysis	30%	3	2	2
Total	100%	3.8	2.45	2.7

#### 4. Wing Configuration

The second viewpoint that was considered was the different sort of wing plans that we could have.

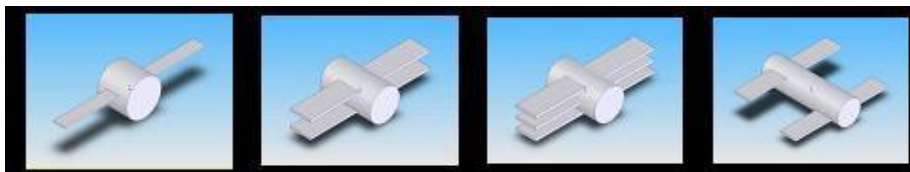


Figure 4: Wing configuration options

Regularly, the effortlessness and execution per weight of the monoplane would make it the leader. In spite of this, the traverse and angle proportion esteems we were going for influenced multi-to wing air ship an appealing alternative. The final result for the wing configuration is delineated in table 3.2.

#### 4.1 Fuselage Design

Fuselage examines concentrated on three unique models.

Table 2: Wing Configuration Score Table

Categories	Weighting	Monoplane	Biplane	N-plane	Tandem
Construction	40%	4	3.5	1	3.5
Flight Performance	30%	3	3.5	3	3
Theoretical Final analysis	30%	3	3	3	3
Total	100%	3.4	3.35	1.1	3.20



Figure 5: Fuselage Configuration Options

The components that influenced the decision of configuration as shown in figure 5 were the wing stacking attributes alongside the ability of stacking adaptability for the distinctive sorts of balls. While the lifting fuselage could conceivably lessen wing stacking, there was the potential issue of executing a low-weight development alongside the over the top airfoil thickness to oblige an assortment of potential burdens. Also, while the wing gave great drag proficiency, an ordinary last plan was observed to be regularly supported inside the model building group because of simplicity of development and general involvement inside the R/C people group about building traditional last airplane. The after-effect of the exchange considers are shown in table 2

Table 3: Fuselage Type Score Table

Categories	Weighting	Conventional final	Blended	Flying Wing
Construction	30%	4	2	3
Weight	20%	2	2	4
Flight Performance	20%	3	2	3
Theoretical Final analysis	30%	4	2	2
Total	100%	3.4	2	2.9

#### 5. Tail Design

At last, Tail configuration concentrated on 3 unique plans as portrayed underneath.

There were various variables that influenced the reviewing in the table beneath. Specifically: While the H-Tail builds adequacy of the level control surfaces through the winglets, it likewise adds expanded weight to the plan since we require various vertical surfaces with their control servos, which may not be significant.

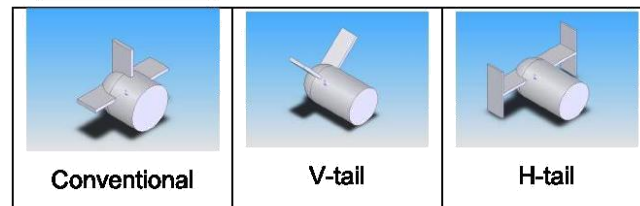


Figure 6: Empennage Configuration Options

While the V-Tail gave various advantages, the group felt that we could get a similar execution attributes from a less complex outline given the speed we were going at. Moreover, no weight was relied upon to be spared by utilizing a more confounded tail plan.

The customary last outline is notable for its okay and simplicity of control and manufacturability. An ordinary last outline is additionally broadly utilized as a part of the R/C people group since it is the most proficient tail outline for the speed R/C planes are relied upon to y it. Table 3 demonstrates the last after effects of the exchange contemplates for tail plan.

Table 4: Empennage Type Score Table

Categories	Weighting	Conventional final	T-tail	V-tail
Construction	40%	4	2	3
Flight Performance	20%	3	3.5	3.5
Theoretical Final analysis	30%	3	2	2
Total	100%	3.25	2.45	2.7

#### *Parameters from Reference Outlines*

Once the outline for the plane was chosen, examine was directed on existing R/C planes.

Coming about reference parameters are appeared here.

Max take-o weight 1.5kg Aspect Ratio 5

CLmax 1:5, Stall Velocity 7 8 m/s

#### *Payload Determination*

Keeping in mind the end goal to evaluate the ideal payload dissemination a plot of the different flight scores versus add up to weight of the flying machine were plotted.

Figure 7 demonstrates the different point disseminations for ping pong/golf ball designs and a 10 tennis ball payload setup. The 600g, 700g, 800g, 900g, and 1kg planes allude to discharge weights of the plane and the Flight score related with stacking such a plane with a stage of golf balls and ping pong balls. The tennis ball arrangement alludes to a plane that is completely stacked with 10 tennis balls. In view of gathering talks and earlier year's plans, a vacant weight of 900g was chosen as a sensible gauge for the void weight of our air ship. For a tennis ball setup that would add up to an aggregate weight of  $900g + 570g = 1:47kg$  where 570g is the heaviness of 10 tennis balls. Taking a gander at Figure 7 it is clear that for a ping pong/golf ball arrangement to give the same flight score as the tennis ball design, the vacant weight would need to be only 700g. Subsequently, our gathering chose our air ship would convey 10 tennis balls as our freight.

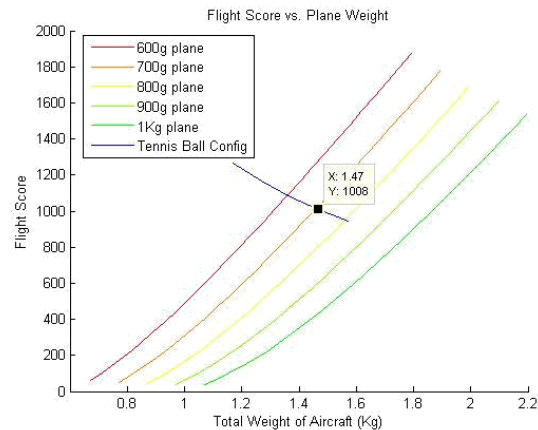


Figure 7: Flight Score Last examination

## 6. Results and Discussion

A model of an air ship was given and the air ship was symmetrical horizontally. The model was then brought into ANSYS WB and was coincided fittingly. Cross section instruments like Swelling and mapping couldn't be utilized while fitting as its giving fine work. Thus this acquires a mistake CFX-Pre. A photo underneath demonstrates the work which was done in this last investigation

Table 5 Specification of the wing

WING SPAN	12.65 m
WING AREA	17.8m <sup>2</sup>
$C_{L\ MAX}$	1.197
WING PLANFORM	Tapered-slight swept wing
STALLING SPEED	31.1m/s
AIRFOIL TYPE	NACA 4412
ASPECT RATIO	5.12
SWEEP ANGLE	5 DEGREES

By utilizing the above subordinates, wing is displayed in CATIA V5R21. Right off the bat the directions of the airfoil (NACA 4412) is foreign made into CATIA through Exceed expectations at that point wing is demonstrated in "wireframe and surface plan" workbench

Material Properties:

The material relegated for wing is 'Aluminium Combination' with given material properties:

Table: 6 Material Properties

Density ( $\rho$ )	2770 kg/m <sup>3</sup>
Modulus of Elasticity (E)	7.1E10 Pa
Poisson's Ratio ( $\nu$ )	0.33
Tensile Yield Strength	280 MPa
Shear Yield Stress (K)	201.5 N/mm <sup>2</sup>
Maximum Allowable Stress	300 N/mm <sup>2</sup>

### Methodology Adopted:

This last investigation was done by utilizing Static Basic module in ANSYS Workbench. As the wing geometry is the gathering of various parts, every one of the parts is "Fortified" to each other.

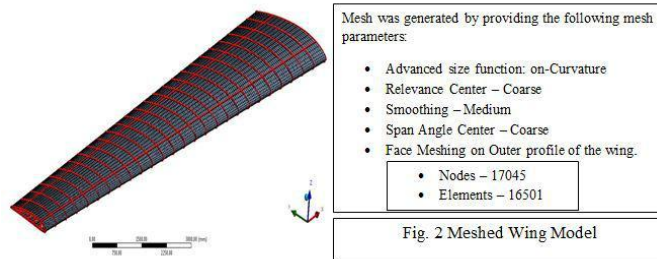


Figure 8 Meshed Wing Model

In the wake of defining up the limit conditions the issue was illuminated to discover the comparable anxiety and most extreme twisting of the wing in Z-Heading with no shear

### Directional Deformation

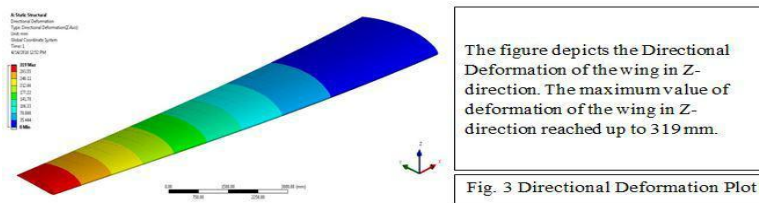


Figure 9 Directional Deformation

### Equivalent Stress:

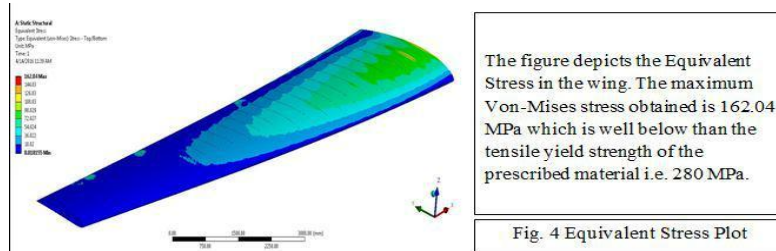


Figure 10 Equivalent Stress

### Modal Final analysis:

Modular last investigation is the investigation of the dynamic properties of structures under vibration excitation. In flying machine because of the lift stack and the heap because of mounting motor on the wing prompts vibration. The modular last investigation utilizes the general mass and firmness property of the structure to locate the different periods at which it will normally reverberate. Calculation of characteristic frequencies and common mode states of a structure could be of extraordinary essentialness. They let us know at what frequencies the structure can be energized into full movement. By and large, this data is adequate for adjusting the basic outline with a specific end goal to diminish commotion and vibration. Likewise, a dynamic collaboration between a segment and its supporting structure is critical in light of the fact that the segment could cause auxiliary harm or disappointment if its working recurrence is near one of the normal frequencies of the structure.

So we continue further and examine the wing structure for various recurrence modes. The work parameters and the limit conditions for the issue would be same as of above. The last investigation was performed to locate the aggregate distortion under 5 modes.

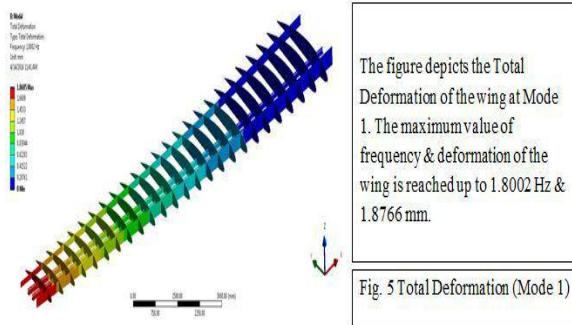


Figure 11 Total Deformation Modes 1

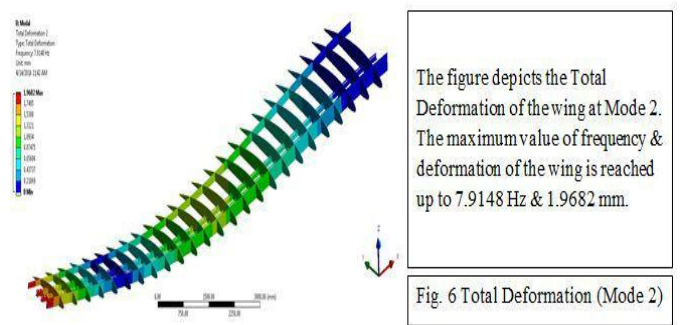


Figure 12 Total Deformation Modes 2

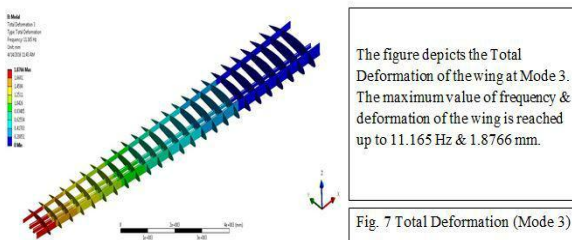
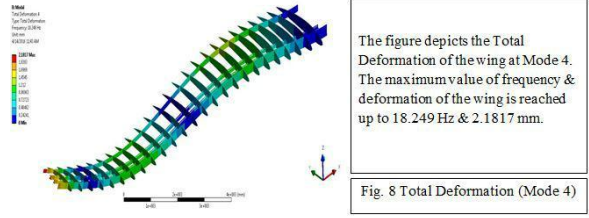


Figure 13 Total Deformation Mode 3



Figures 14. Total Deformation Mode 4

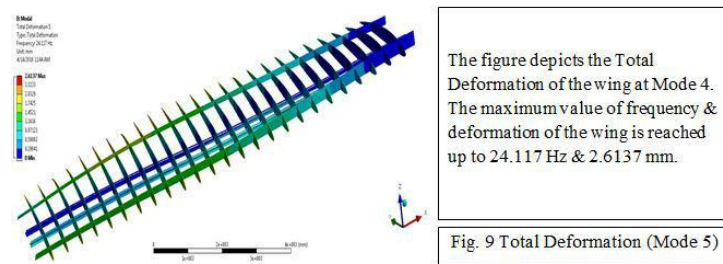


Figure 15 Total Deformation Modes 5

Table 7 Natural Mode shapes and Frequencies

S.No.	Mode Shape	Frequencies (Hz.)
1.	1	1.8002
2.	2	7.9148
3.	3	11.165
4.	4	18.249
5.	5	24.117

Table 8: Angle of attack vs coefficient of lift

Angle of attack	Coefficient of drag
1.49	0.0201
2.00	0.0209
5.00	0.0331
10.00	0.0581
15.00	0.0668
18.00	0.0714

Table 9: Coefficient of drag values at different angle of attack

Angle of attack	Coefficient of lift
1.49	0.1801
2.00	0.2823
5.00	0.5688
10.00	0.8584
15.00	1.223
18.00	1.384

## 7. Conclusion

This work displays the mimicked stream over an air ship and it was watched that the lift increments as approach increments and if the approach is expanded, focus of weight pushes ahead and on the off chance that it is diminished, it moves rearward or towards trailing edges and focal point of gravity is settled at a certain point.

For an approach 1.49deg with a speed 250m/s it was watched that the greatest speed is 308.3m/s and aggregate weight is 22408Pa, and related coefficient of lift is 0.1801

At 10deg approach with speed 250m/s watched most extreme speed is 286m/s, add up to weight is around 23056Pa, coefficient of lift and coefficient of drag are 0.8584 and 0.0501 individually.

The lift and drag rely upon the airfoil shape and it is relying on the speed circulation, yet additionally on the wing platform and on the wing region. It is conceivable to compute the aerodynamic properties of differently sized airfoils or wings if all forces and moments are normalized.

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