International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 5, Issue 5
May 2018

Optimizing a Smart Network for Structural Health Monitoring of a Composite Wing

Ritesh Pal
UG Student, Aeronautical Engineering, MVJ College of Engineering, Bangalore
Sahil Thakur
UG Student, Aeronautical Engineering MVJ College of Engineering, Bangalore
Patel Sunny Shirishbhai
UG Student,Aeronautical Engineering MVJ College of Engineering, Bangalore
Suraj Sarjerao Gholap
UG Student, Aeronautical Engineering MVJ College of Engineering, Bangalore
Vishnu Raj
Assistant Professor, Aeronautical Engineering, MVJ College of Engineering, Bangalore

ABSTRACT

There has been a significant increase in the use of Fiber Reinforced Plastic in aircraft industries. This is because, FRPs have advanced desirable properties when compared to traditional metal materials. However, the laminated nature of FRPs still remains a challenge as this leads to relatively weak out of plane properties and may lead to failures such as delamination or matrix cracking. There are also invisible damages that are difficult to evaluate. A promising way to utilize the full potential of FRP is to detect and monitor the internal damage state, thereby setting up proper safety threshold and reducing the risk of catastrophic failures. There are many existing traditional methods that are being used to monitor the structural integrity of the composites, but they have their own drawbacks. An interesting route towards multifunctional composite materials with integrated Structural Health Monitoring (SHM) is to use Carbon Nano Tubes (CNTs) in Fiber Reinforced Composites, as this provides not only integrated damage sensing capabilities but also leads to additional mechanical reinforcement. This will be done by modal analysis of an aircraft wing made up of Fiber Reinforced Plastic (FRP). The possible region where the aircraft is likely to fail will be analyzed, to obtain the nodes and the antinodes. Based on this result, the best possible network for layering up the CNT will be obtained. The CNTs will be then integrated with the wing on the obtained network. The resultant structure would be a smart material that would be able to detect the formation of crack at a nanoscopic level. Once the objective is achieved, based on the feasibility of the application, substitutes like optical fiber or other smart materials can be assigned for continuous SHM of critical aircraft component

KEYWORDS

Structural Health Monitoring, Carbon Nano Tubes, Modal Analysis

1. INTRODUCTION

A damage detection and characterization strategy for engineering structures is referred to as structural health monitoring (SHM). Here damage is defined as changes to the material and/or geometric properties of a structural system, including changes to the boundary conditions and system connectivity, which adversely affect the system's performance. The SHM process involves the observation of a system over time using periodically sampled dynamic response measurements from an array of sensors, the extraction of damage-sensitive features from these measurements, and the statistical analysis of these features to determine the current state of system health. For long term SHM, the output of this process is periodically updated information regarding the ability of the structure to perform its intended function considering the inevitable aging and degradation resulting from operational environments.Aircraft are highly complex systems composed of various structural, hydraulic, propulsion,electronic and avionic elements. Such complex systems require extensive maintenance.A major portion of the maintenance effort of aircraft structures is related to healthand usage monitoring. The other significant portion of maintenance involves repair orreplacement. All of this evolves from the safety criticality aspects that must be seteither prior to design or during in-service as a result from a changing operational environment. Determination of incidents where inspection becomes essential is either established by a prescribedinspection sequence and procedure and/or by monitoring the actual load sequence the aircraft has gone through. Current inspection techniques include visual observations, eddy current and ultrasonic. In-situ structural monitoring is particularly important for airframes. Lightweight and stiff aircraft structures are designed to withstand severe operational conditions and possible structural damage. This would not be possible without appropriate design concepts, advanced materials and maintenance effort.Current aircraft structures are mostly built using metallic and polymer composite materialswith metal-matrix composites in very exceptional cases. The mechanism of damage inthese materials depends on the ductility and homogeneity. Materials, such as aluminum,develop cracks. Microscopic cracks generating in the grains of a metal propagate in therespective component during the life-time under variable loading conditions. Severe andunexpected loads or impacts can lead to significant plastic deformation on componentsurfaces. Polymer based composite materials do generate other mechanisms of damagewhere barely visible impact damage (BVID) is the mechanism of major concern.

2. METHODOLOGY

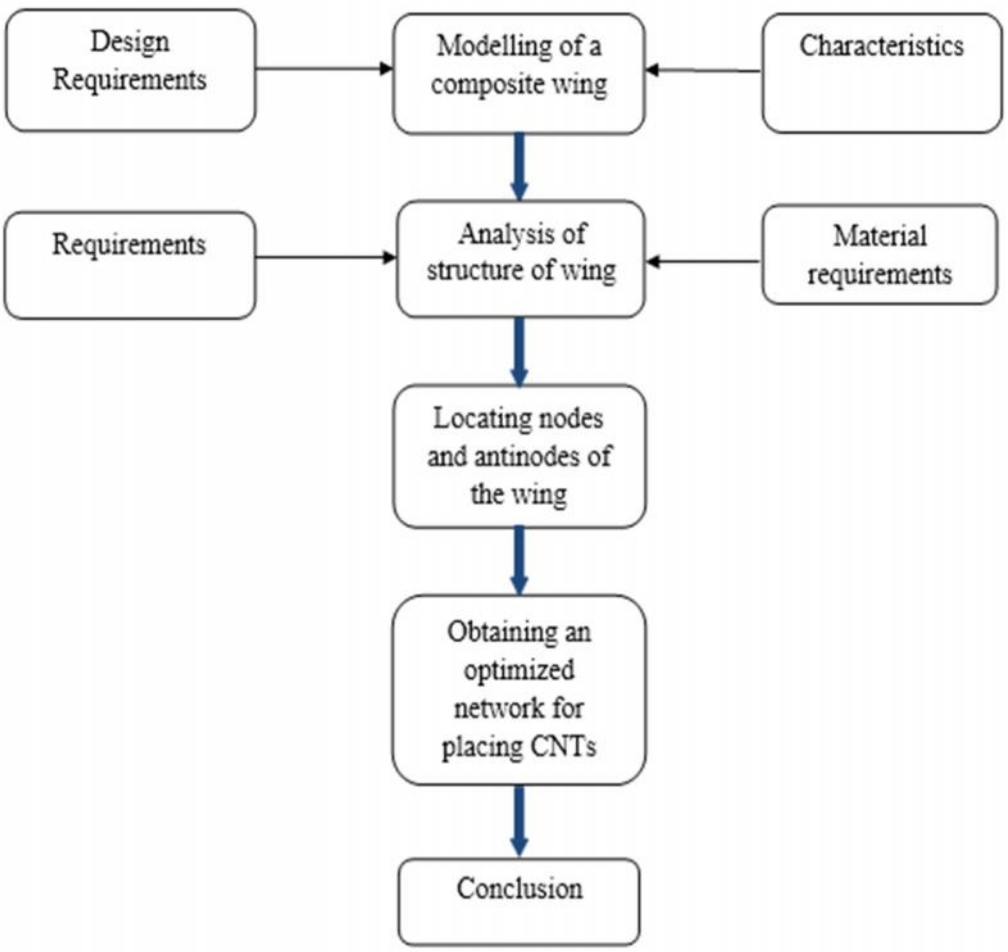


Figure 2.1: Flow Chart of Methodology

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 5, Issue 5
May 2018

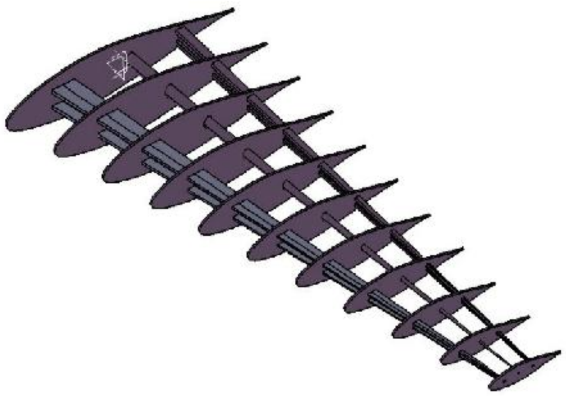
3. WING DESIGN

While designing an aircraft wing you have to consider Fuselage. We have to estimate the maximum take-off weight of an aircraft. The maximum take-off weight is estimated to be 44,000 kg. We have taken the reference aircraft as Boeing 777. The parameters to be considered while designing a wing are Ideal lift coefficient C_{Li}, Maximum lift coefficient C_{Lmax}, Root Chord Length C_r, Tip Chord Length C_t, Breadth of the wing b_{eff}, Type of flow, Type of Airfoil. All design parameters have been calculated and is tabulated below.

Parameters	**Value**
Aspect Ratio, AR	6
Wing Planform Area, S	30 m^2
Breadth of the wing, b_{eff}	13.41 m
Root Chord, C_r	2.23 m
Tip Chord, C_t	1.33 m
Taper Ratio, λ	0.6
Ideal lift coefficient, C_{Li}	0.5
Maximum lift coefficient, C_{Lmax}	1.79
Airfoil Type	NACA B737-IL

Table 3.1: Parameters of the Wing

Based on the above parameters wing is designed in Catia V5. The design is given as follows



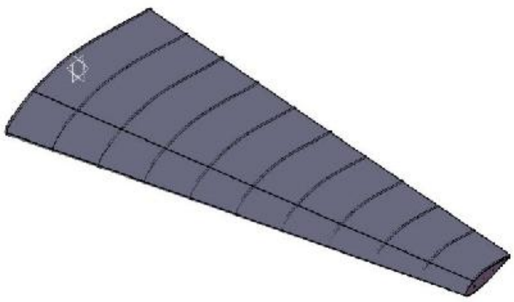


Figure 3.1: Designed Wing in Catia V5

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 5, Issue 5
May 2018

4. WING ANALYSIS

The designed model in Catia V5 is imported to Ansys Workbench and done a modal analysis to find out the nodes and antinodes of the wing.

4.1 Material Properties

The material properties of all the elements of the wing is given below, for skin of the wing we are using Glass Fiber Reinforced Polymer (GFRP), for Ribs and Spars we are using Aluminium alloy for sensors we are using Carbon Nanotubes (CNT)

Material	GFRP	Aluminium Alloy	CNT
Young's Modulus	EX= 36 GPa EY= 13 GPa EZ= 13 GPa	E= 71000 MPa	E= 950000 MPa
Shear modulus	4.3 GPa	-	-
Poisson's Ratio	0.22	0.33	0.3
Density	2170 Kg/m^3	2770 Kg/m^3	1400 Kg/m^3
Tensile yield strength	626 MPa	-	-
Compressive yield strength	230 MPa	-	-
Shear strength	48.7 MPa	-	-

4.2 Meshing

The Element size is given as 0.1mm. Meshing is done using tetrahedral mesh.

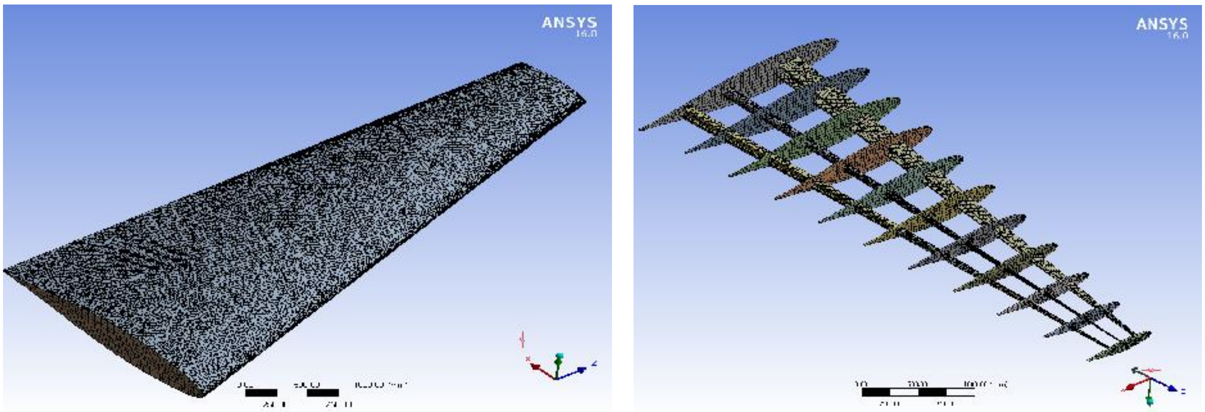


Figure 4.1: Meshed view of Wing

4.3 Boundary Conditions

The boundary condition is very important while doing an analysis. For our analysis we are fixing the wing at one end and applying pressure load at the tip.

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 5, Issue 5
May 2018

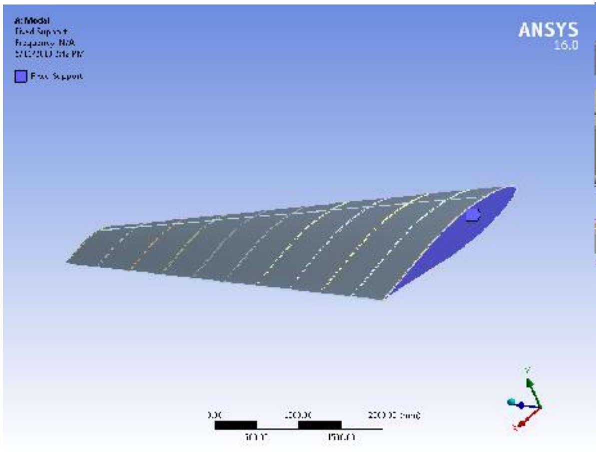


Figure 4.2: Fixed at one end

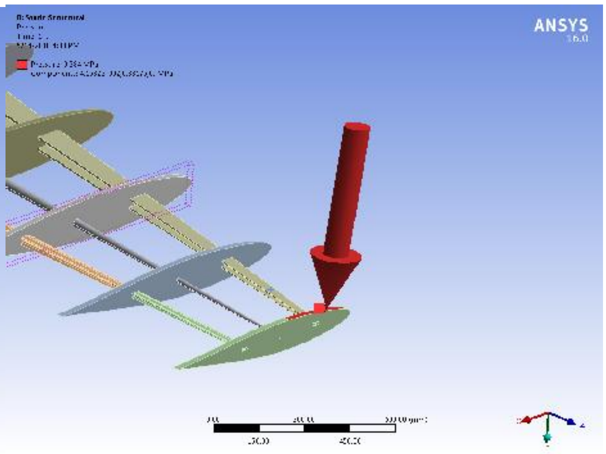


Figure 4.3: Pressure acting at top edge0.3Mpa

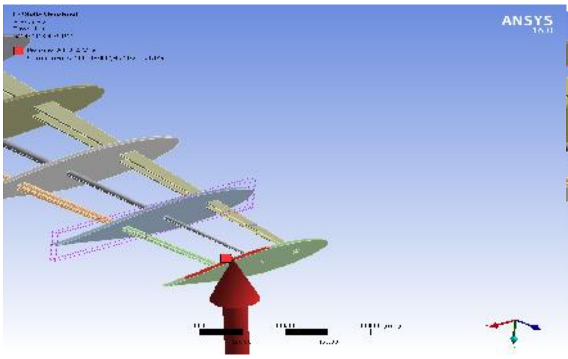


Figure 4.4: Pressure acting on Middle top edge0.2 MPa

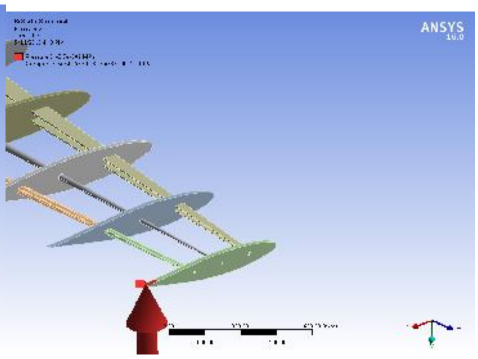


Figure 4.5: Pressure at rear edge is -0.037 Mpa

Property	Value
Mesh Size	0.1 mm
Pressure acting at top edge in downward direction	0.38 MPa
Pressure acting at mid-bottom of bottom edge	-0.02 MPa
Pressure acting on bottom edge	-0.073 MPa
Pressure acting on back side of rear edge	0.03 MPa

Table 4.1: Boundary Conditions

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 5, Issue 5
May 2018

4.4 Mode Shapes

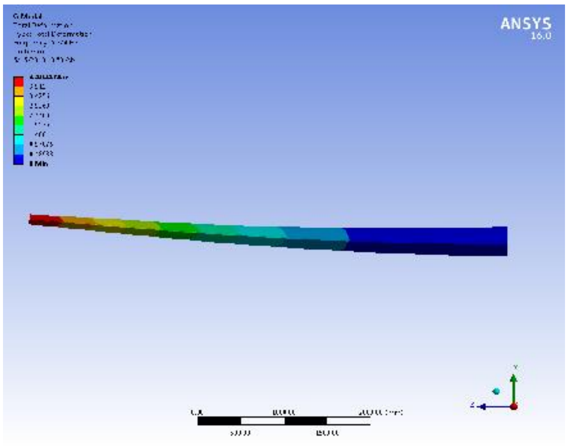


Figure 4.6: Mode 1

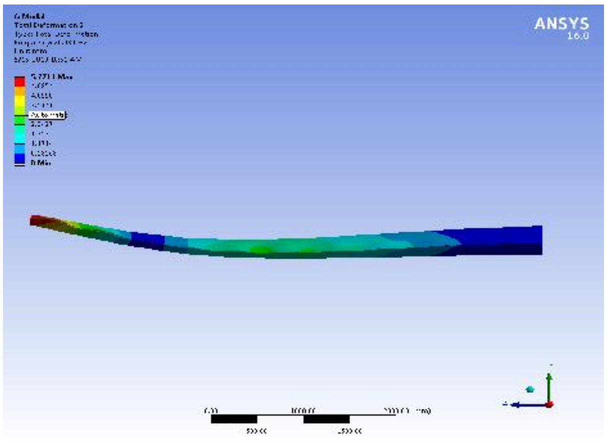


Figure 4.7: Mode 2

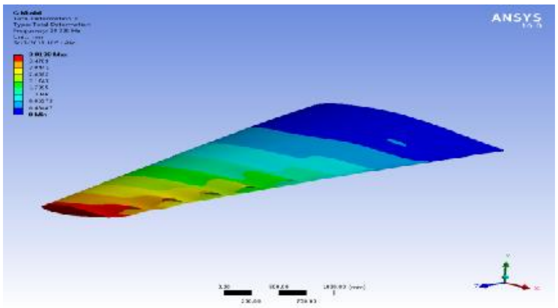


Figure 4.8: Mode 3

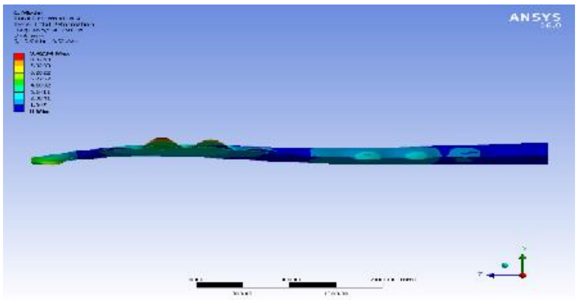


Figure 4.9: Mode 4

Similarly we have found out 10 mode shapes of the designed wing through modal analysis of the wing. Based on the 10 mode shapes 10 natural frequencies is found out. Every mode shapes will have one anti node the position is given in the table.

Mode	Natural frequency (Hz)	Antinode number
1	6.224	95436
2	20.031	95436
3	38.399	96035
4	40.258	95658
5	41.526	95547
6	53.07	140422
7	55.081	95254
8	55.752	141427
9	57.739	95315
10	58.35	141427

The optimized network is found out by connecting all the Antinodes by CNT. The CNT tube is modeled along anti-nodes in CATIA with 30 Microns as radius.

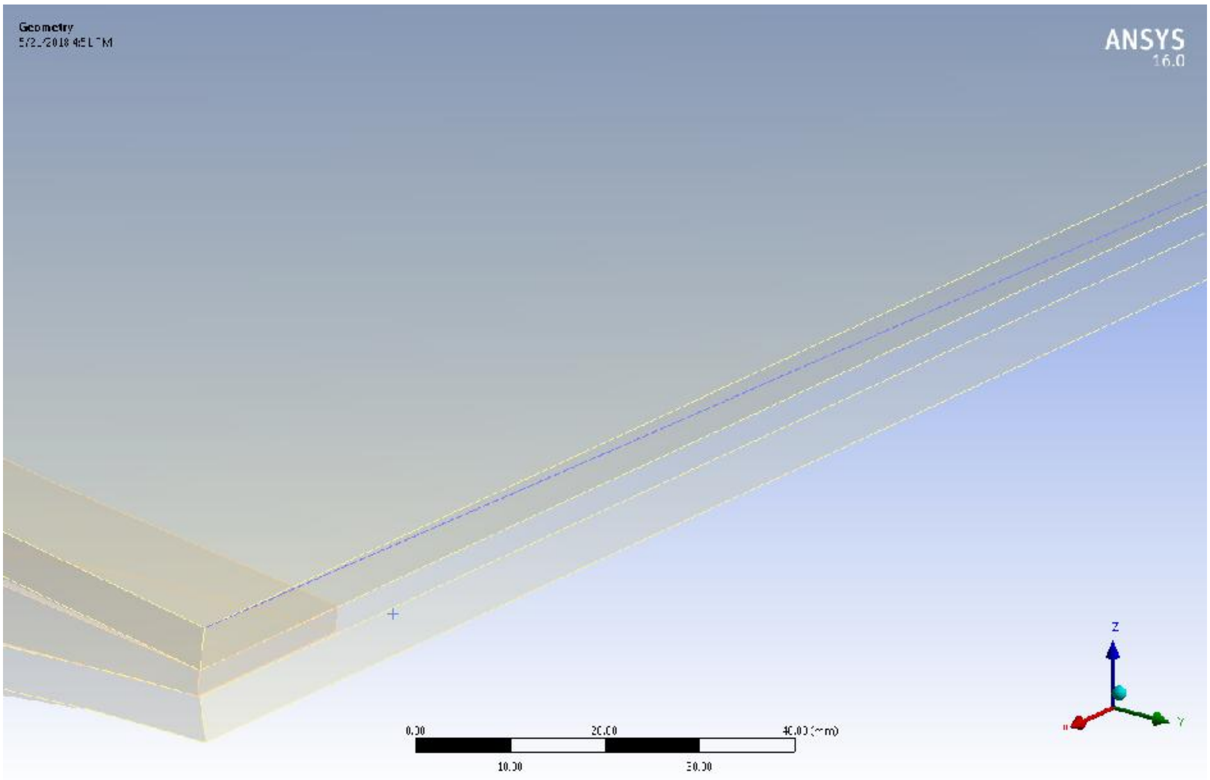
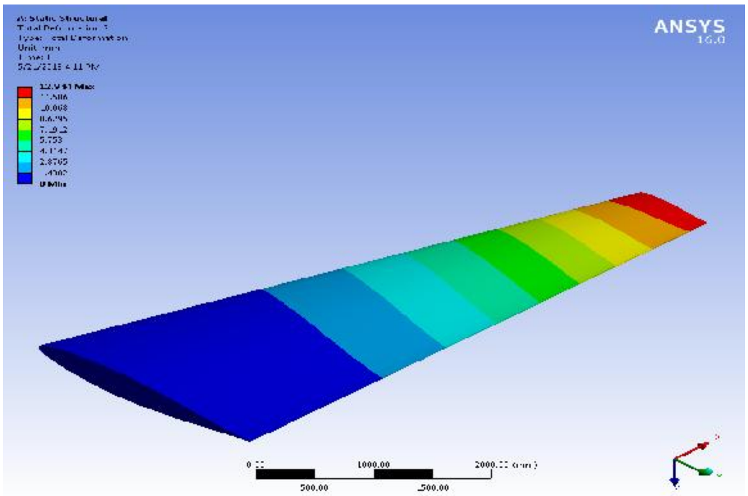


Figure 4.10: CNT Geometry Plot in Ansys

The Wing which is reinforced with CNT is Analysed again in Ansys. Both structural and modal analysis is done. And it is found out that deformation is 12.94 mm with CNT tube and deformation without CNT is 12.94. The natural frequency is also got reduced due to reinforcement of CNT in Composite wing.



5. CONCLUSION

The reinforcement of carbon nano tubes in a composite wing will leads to enhanced mechanical capabilities and also this can be used for structural health monitoring for composite wing.

REFERENCES

[1] Mohamed A Sadrey, " *Aircraft Design: A system engineering Approach*"
[2] Fuh-Gwo Yuan ," *Structural Health Monitoring in Aerospace Structures*"
[3] Michael Chun-Yung Niu, "*Airframe Structural Design*"
[4] Alan Baker, Stuart Dutton, " *Composite Materials for Aircraft Structures*"
[5] T.A Stolarski, Y Nakasone, "*Engineering Analysis with Ansys Software*"