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Optimizing a Sensor Network for Structural and Usage Health Monitoring for a Tapered wing

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***Abstract*— A damage detection and characterization strategy for engineering structures is referred to as structural health monitoring. Here damage is referred as changes to the material property of a structural system. The wing structure of an aircraft carries different load which should be monitored effectively to avoid the failure of the wing.This research is focused on structural health and usage monitoring of tapered wing of an aircraft, sensors are used to measure the strain. The research focuses on the location where we can place the sensors and optimize the network for sensor placement.**

***Keywords*— Structural Health Monitoring, Tapered wing, Sensor Network, Modal Analysis, Fibre Bragg Grating Sensors**

I. INTRODUCTION

An aircraft is a complex structure which is subjected to various loading conditions. Such complex structure require extensive maintenance. Structural health monitoring emerged as a multidisciplinary set of technologies with goal of reducing maintenance costs in aircraft structures by the implementation of automatic damage detection systems, able to detect incipient cracks well below the critical size, and nearly without human intervention. Inspection of structural integrity could be done almost continuously either during flights or overnight stops without aircraft disassembly. The system could include three key elements, a network of sensors permanently attached to the structure, on-board data handling computing facilities, algorithms that collect data from sensors. Non Destructive Evaluation techniques of inspection which uses external equipment to monitor the behavior of the structure. In the case of Structural Health Monitoring and usage monitoring systems, the systems which is consists of data handling and data acquisition is permanently attached to the structure itself.

II. METHODOLOGY

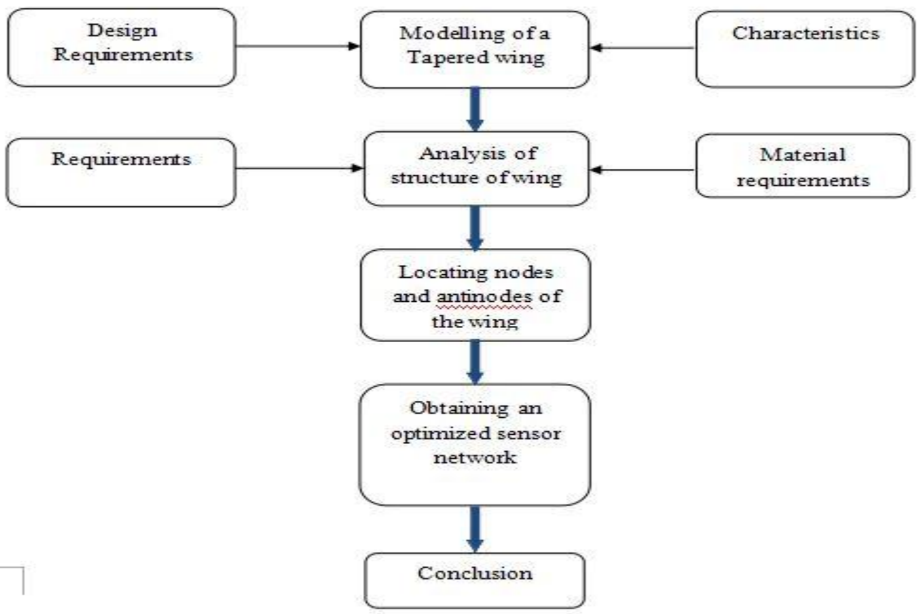

Figure 1: Methodology for the Research

III. 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 1: PARAMETERS FOR THE TAPERED WING

Based on above parameters tapered wing is designed in Catia V5

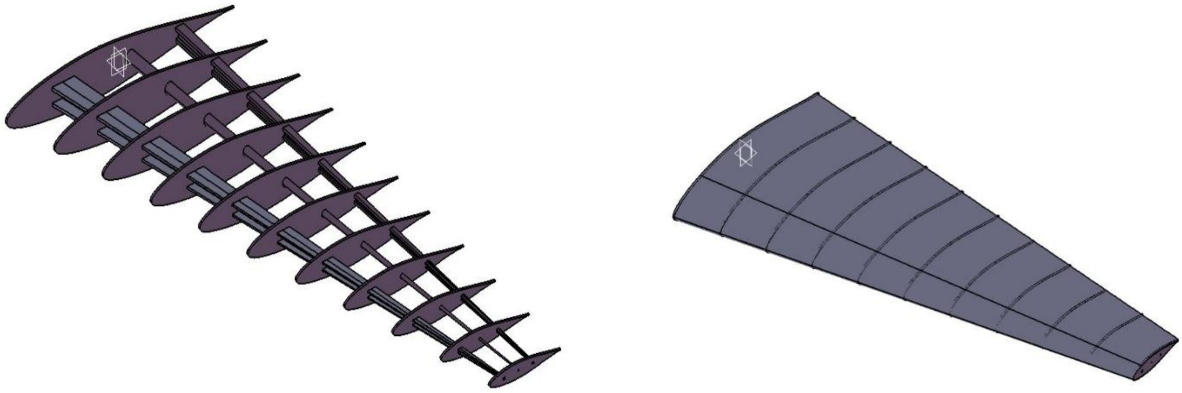

Figure 2: Designed Wing in Catia V-5

IV. 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.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.

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

Table 2: Material Properties

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

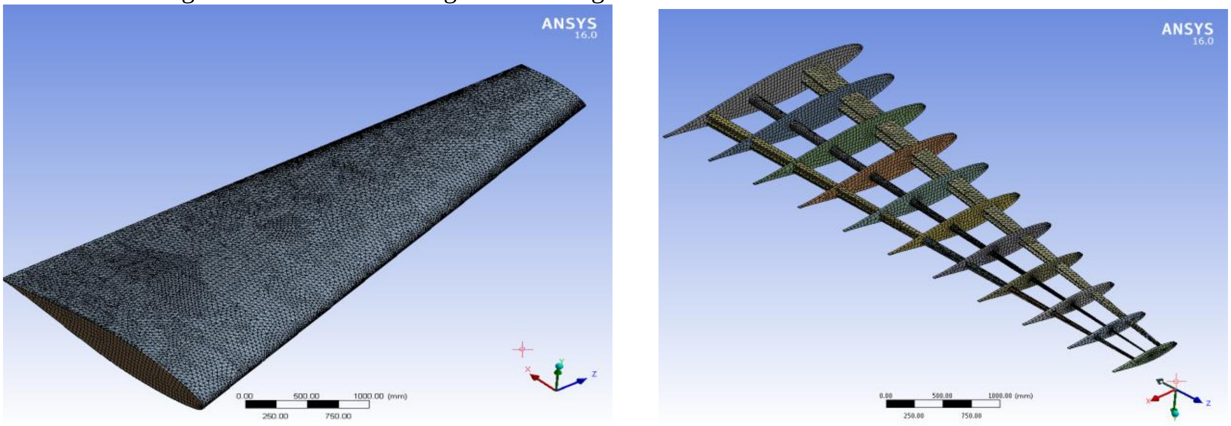

Figure 3: Meshed View of Wing

V. MODE SHAPES

Mode shapes are the behavior of a structure at a certain frequency. The mode shapes of tapered wing is found out to obtain the maximum deflection point which in turn will give the nodes and anti nodes. The mode shapes of the wing is shown below.

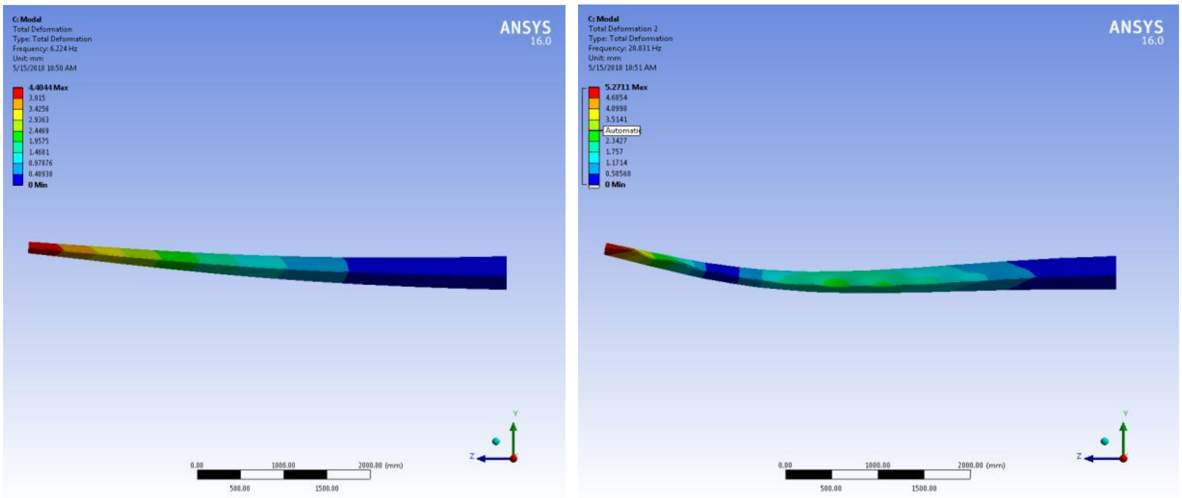

Figure 4: Mode 1 and Mode 2

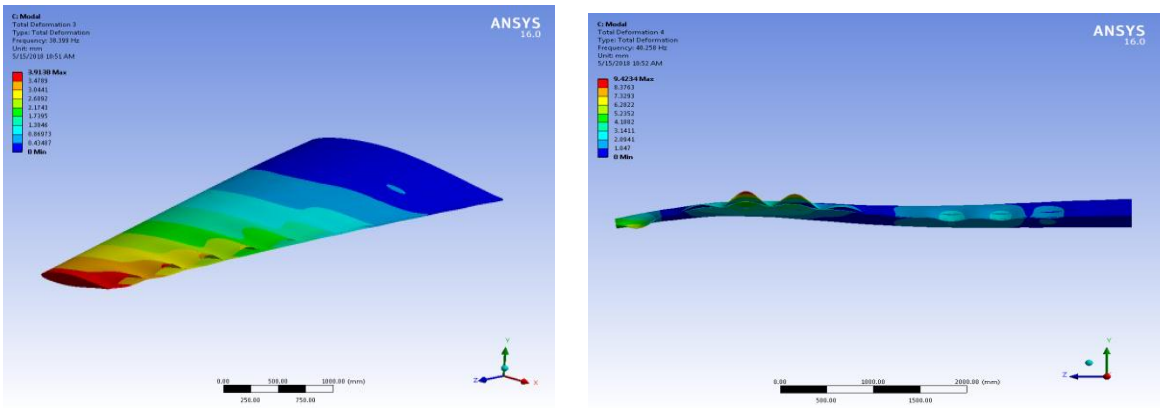

Figure 5: Mode 3 and Mode 4

Similarly we have found out 9 mode shapes of the designed wing through modal analysis of the wing. Based on the 9 mode shapes 9 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	57.739	95315
9	58.35	141427

Table 3: Natural Frequency and Anti Node Number

VI . OPTIMIZING SENSOR NETWORK

The maximum deflection points found by modal analysis using ANSYS software are noted. This points has been marked on the tapered wing design. This maximum deflection point are connected by using spline to form a network.

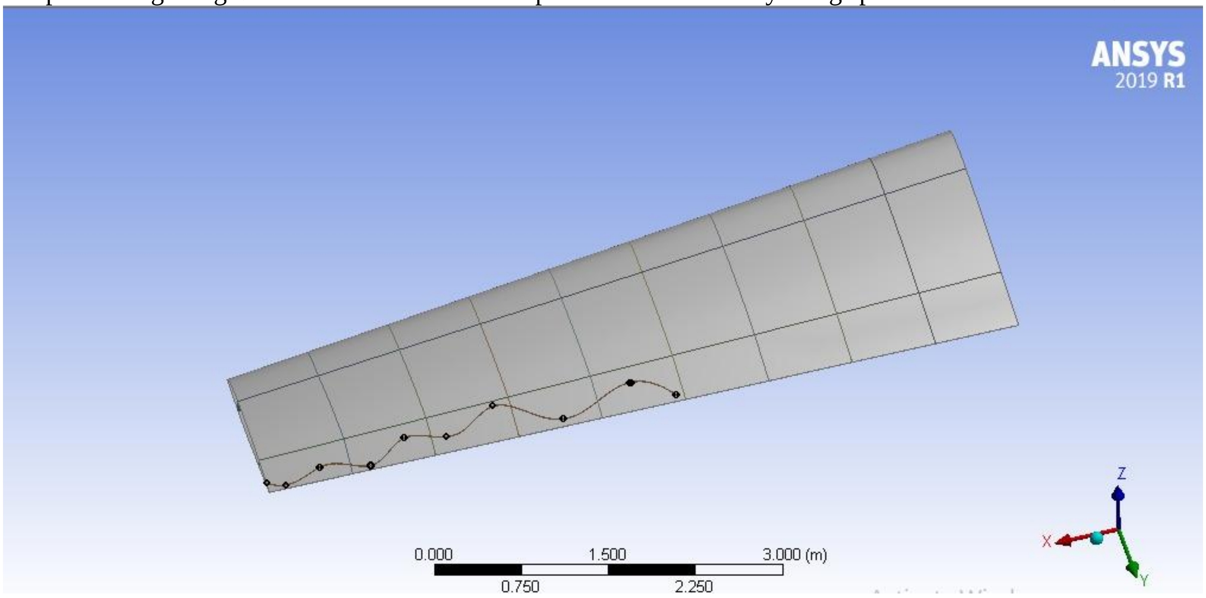

Figure 6: Sensor Network

From the literature survey we can conclude that the sensors which can be used for aircraft application is Fibre Bragg Grating Sensors (FBG) since it is very light and it can be tailored by means of design process.

VII. CONCLUSION

Structural Health Monitoring plays a vital role in the maintenance of strategic structures. The main advantage of Structural Health monitoring is it can reduce or avoid the downtime of strategic structures. Wing structure is one of the major component of aircraft structure which provides the lift, and which is subjected to various types of loading at various phases of mission of an aircraft. The monitoring of wing structure is very important. Tapered wing is designed in Catia V5 and modal analysis is done in Ansys Workbench to estimate the maximum deflection points. This deflection points is the point where we are going to place the sensors. By finding out the different points we will get the network layout of sensors. There are different types of sensors which can be used for SHM application, for aircraft applications it is suggested to use Fibre Bragg Grating Sensors since it is very light in weight as well as very easy to employ.

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