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OPTIMAL LOCATIONS OF PIEZOELECTRIC PATCHES FOR VIBRATION CONTROL USING HARMONIC ANALYSIS IN AIRCRAFT WING

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ABSTRACT-*Aircraft wing structures are obligatory to be lightweight in today's designs. However, this lowers the overall stiffness of the wing structure and causes low frequency vibration problems. Active vibration control using piezoelectric patches is an auspicious technology to solve vibration problems of aerospace structures .Many studies were done on aircraft wing geometries, however studies on beam geometry which is used comprehensively as engineering structure, is relatively erratic. The main characteristics of this work were amplification of a finite element model for a plate stiffened by wing surface. Finite element model of the aircraft wing is generated. This study is a postponement of the wing reading with the toting of determining the harmonic analysis to optimal mode shapes of the wing structure. First eight mode shapes used to fine the maximum structure deformation with various frequencies by applying the piezoelectric patches in various locations. From the harmonic analysis we can identifies the exact location of placing the piezoelectric material in the wing structure.*

Keywords- *Active vibration, Harmonic analysis, Piezoelectric patch, Wing structure.*

1. INTRODUCTION

The piezoelectric effect was discovered in 1880 by Pierre and curie, and the inverse piezoelectric effect by Gabriel Lippmann in 1881. The relationship between mechanical properties and electrical properties in piezoelectric materials, and their use in divergent forms such as patches and layers, make piezoelectric materials a good choice for use as sensing and actuating elements. Using the direct piezoelectric effect, mechanical or thermal deflection in structures can be calculated by measuring the created electrical potential in piezoelectric materials. On the other hand, the inverse effect can be used to control deflection or strain in structures by applying suitable electrical potentials to attached piezoelectric materials. Hence, piezoelectric patches can be used as sensors and actuators which are incorporated into the design of structures to achieve high strength, low weight and having self-control capability. In recent times, this technology has been used in various applications such as active vibration control, control of deflections in structures and the airspace industry.

2. ACTIVE VIBRATION CONTROL

Active vibration control is the active application of force in an equal and opposite fashion to the forces imposed by external vibration. Most machines and structures are required to operate with low level of vibration as smooth-running leads to reduced stresses and fatigue and little noise. Vibration is often limiting factor in performance of many industrial system. Use of passive damping is effective at higher frequencies, but often of little use at lower frequencies. Passive vibration control treatments are unable to adopt or retune to changing disturbance or structural characteristics, over time. Active vibration control systems have emerged as viable technologies to fill this low frequency gap. They do not penalize the weight sensitive structures by adding excessive weight to them.Decreasing of systems vibration is an important issue for all mechanical structures like an aircraft wing where it is subjected to many type of disturbance. Many methods were proposed to decrease or even to eliminate such vibrations by using many techniques like changing the design of structure or even trying to change the materials of studied structures, but until now the problem is with completely manufactured structures in which the designer can't change material, so utilizing controlling method may serve as a tool to apply active vibration control on vibrated structure where by which one convert passive structure to smart structure.

3. WING DESIGN: CATIA MODEL

An aircraft wing has been modeled in a CATIA. A model was constructed by using CATIA modeling software, ZODIAC CH 650 aircraft wing was modeled closely to the real one. This wing is mainly containing two spars each one is located at 25% of chord length from both leading and trailing edge respectively. NACA 0015 is the airfoil section of the mentioned wing with 8 ribs along the wing's length, the distance between the each rib is 0.375m which is continuously exceeded along the wing length of 3m. The tapering ratio of the wing was 0.5 in X and Y coordinates, chord length of the root section of the airfoil is

1.6m, total length of the wing is 3.3m, each ribs was equally distributed along the 3m length of wing section passing through the eight ribs with similar tapering ratio in Y direction only. The remaining 0.3m of spars length is used to mounting the wing with airplane body.

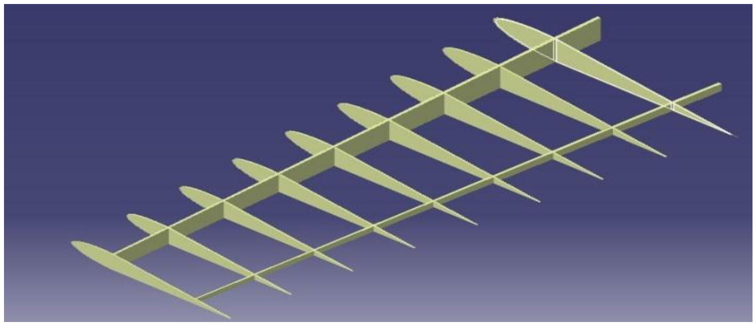


Fig:3.1Airfoil CATIA sketch

4. FEA MODELLING

The wing has 1.6m chord length and 3.3m total length is modeled by using CATIA modeling software, then it will be imported into ANSYS via IGS file. In an ANSYS the material has been selected by engineering data sources. There are two materials selected for analysis. The materials are Aluminium and PZT 5H. Wing interior parts (8 Ribs & 2 Spars) and skin structure material assigned by Aluminium. Piezoelectric patch material is assigned by PZT 5H properties.

Table 4.4 Nodes and element of the geometry

Bodies	5
Active bodies	5
Nodes	50992
Elements	15829

5. FREE VIBRATION ANALYSIS

Free vibration analysis or harmonic analysis is done by using ANSYS workbench. The first 8 modes shapes are calculated in the analysis, which gives the deformation in the wing structure with various frequency.

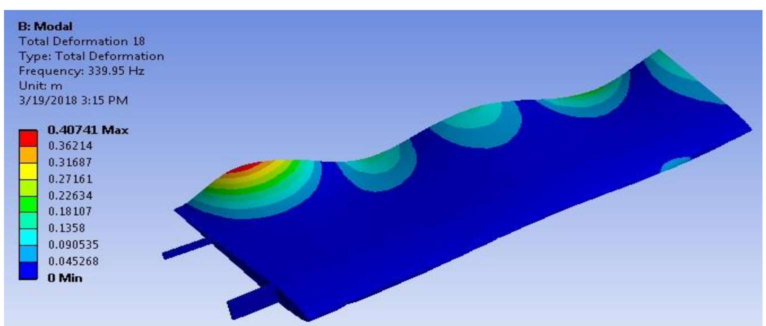


Fig: 5.1 First modes at frequency of 13.958 Hz

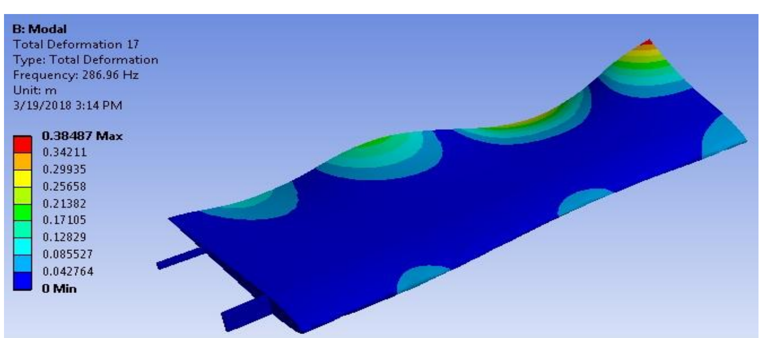


Fig: 5.2 Second modes at frequency of 63.543 Hz

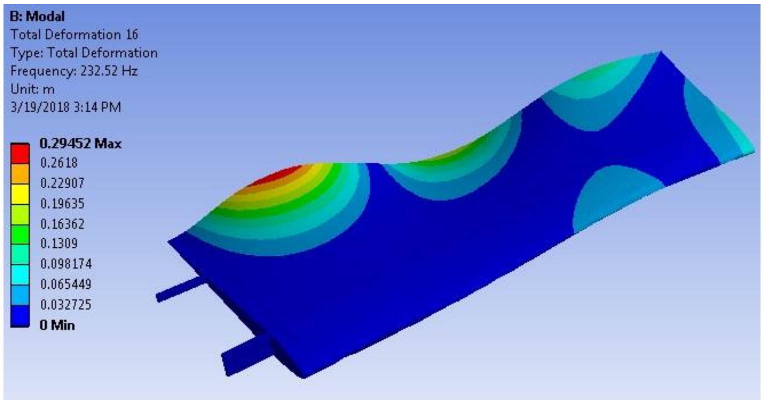


Fig: 5.3 Third modes at frequency of 74.351 Hz

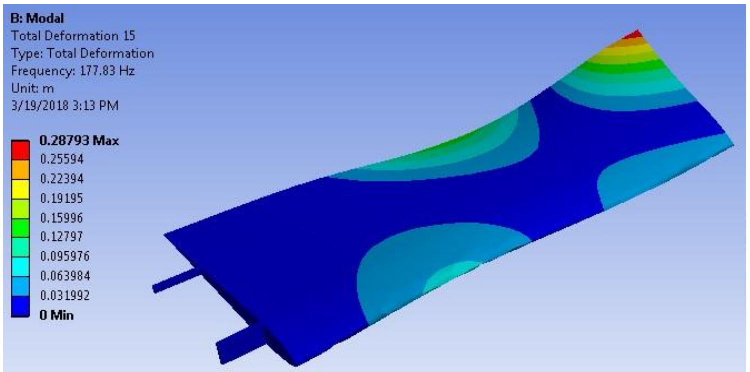


Fig: 5.4 Fourth modes at frequency of 125.04 Hz

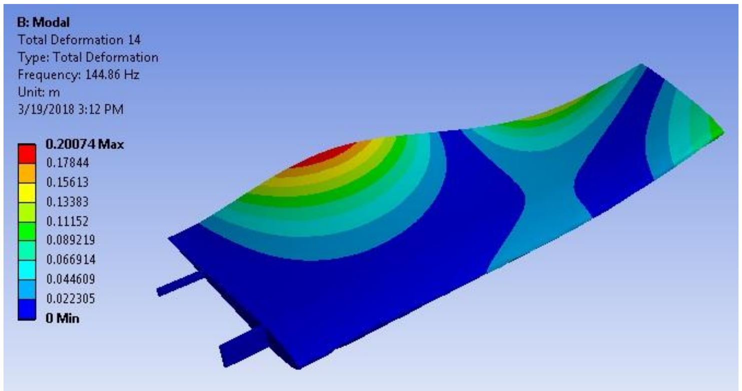


Fig: 5.5 Fifth modes at frequency of 144.86 Hz

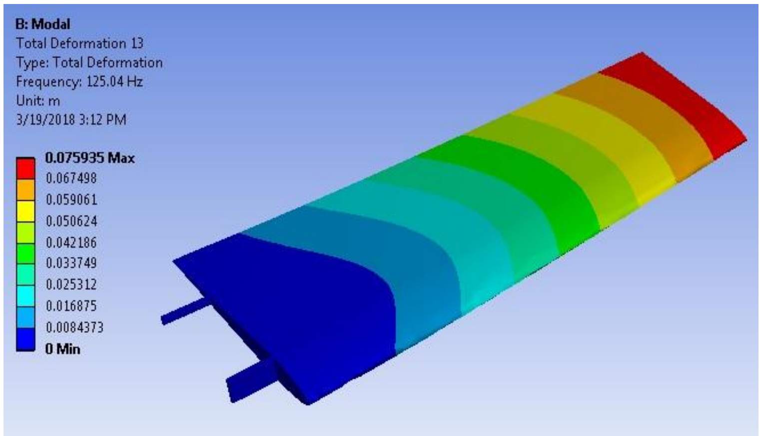


Fig: 5.6 Sixth modes at frequency of 177.83 Hz

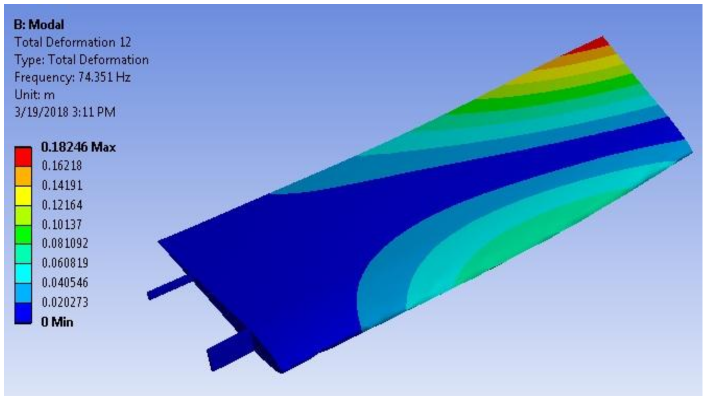


Fig: 5.7 Seventh modes at frequency of 232.52 Hz

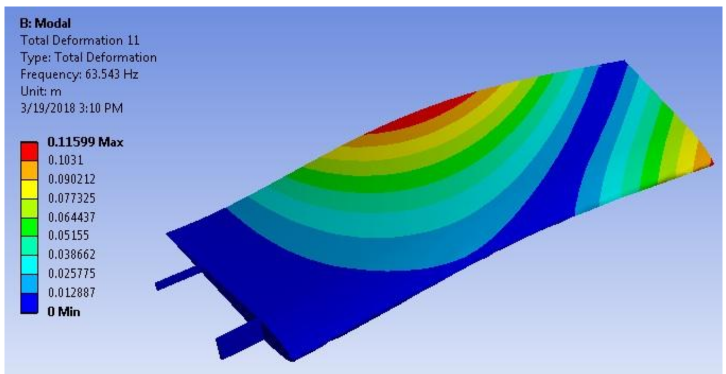


Fig: 5.8 Eight modes at frequency of 286.96 Hz

6. RESULTS AND DISCUSSION

From the analysis the frequencies in various mode shapes give the minimum and maximum deformation of structure. In which the both case of with and without piezoelectric patch location can be easily calculated.

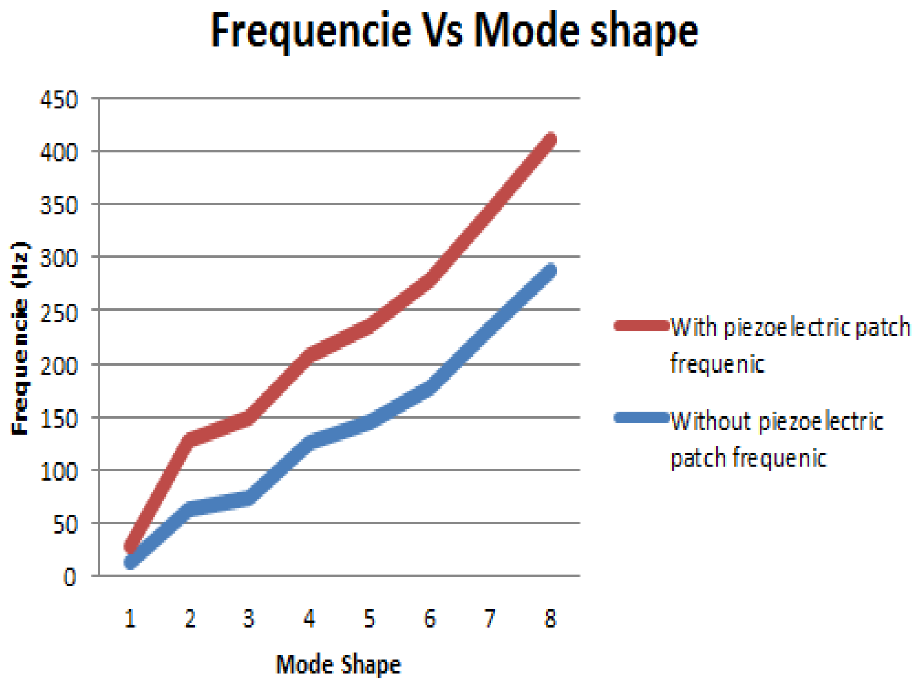
6.1 Frequency without Piezoelectric Material Patch

Mode	Free vibration Frequency [Hz]
1.	13.958
2.	63.543
3.	74.351
4.	125.04
5.	144.86
6.	177.83
7.	232.52
8.	286.96

6.2 Frequency with Piezoelectric Material Patch

Mode	Free vibration Frequency [Hz]
1.	14.334
2.	64.018
3.	74.247
4.	81.845
5.	91.017
6.	101.08
7.	111.04
8.	122.59

With and without piezoelectric patch the mode shape frequencies



7. CONCLUSION

This study carried out about theHarmonic Analysis in the wing with placing the piezoelectricpatch materials. The geometry of this structure is modeled using CATIA and the Harmonic analysis is done by using ANSYS WORKBENCH. Then the model is meshed, appropriate boundary conditions applied and then solved.This study is carried out in order to gain Numerical analysis knowledge on wing structure vibration.In the harmonic analysis the possible mode shapes of the wing structure are evaluated. From this mode shape we can conclude the maximum displacement of the wing with various frequency give the optimized location of placing the piezoelectric material to control the vibration in the wing structure.

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