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Reducing the Vibration on Wing by Using Piezoelectric Actuator

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Abstract: Recent achievements in the application of active materials induced-strain actuation to counteract aero elastic vibration effects in fixed wing aircraft are reviewed. Piezoelectric has been implemented as actuators into an active composite wing. The goal of our project is to design of a wing for a fixed wing aircraft with a thin profile and integrated roll control with piezoelectric actuator elements. Though widely used, conventional technologies for active control of vibrations have severe limitations such as buffet suppression, gust load alleviation is discussed. The piezo electric actuator to be placed in between ribs of fixed wing aircraft. The purpose of using actuator is to be reduces the vibration in the wing area. The active wing with piezoelectric actuator flight control constitutes one of the first examples where such a design has been optimized and the numerical model has been validated in experiments. Conclusions and directions for further work are presented.

1. INTRODUCTION

Formation of structural vibrations on the aircraft, which plague modern high speed aircraft for several decades, but the task, has been a challenging one. Often, structural vibration modes are excited as a result of the interaction between the differential pressures associated with turbulent airflow and aircraft structures and control surfaces.

This aero elastic phenomenon is commonly referred to as buffet. Buffet-induced vibrations have been problematic for aircraft for many years and, if not addressed, can lead to the failure of structural components. Buffet has been a costly problem, not solely in terms of the expense of repairing and replacing aircraft components, but also in terms of the impact it has had on mission availability and performance. Buffet affects a wide range of aircraft and aircraft structures, but its impact has proven to be particularly troublesome for conventional commercial aircraft. Shortly after the Boeing-737was placed in service and many high-angle-of-attack manoeuvres had been executed, fatigue cracks were discovered in the horizontal structural members of multiple aircraft. Eventually, an investigation confirmed that buffet was the cause. In 2000, the cost of repairing the structural members are replaced cause by major defects. In flight, induced vibrations forced due to the fatigue damage and speed at which certain manoeuvres could be flown. So that the conventional aircraft wing may cause by gust load alleviation on their skin surfaces. To reduce the vibrations on the aircraft structural members should be one of the catastrophic problems. Many researches are going on; to reduces these much of vibrations on the wing structural members. This may cause to provide fatigue or crack on the horizontal structural members.

2. METHODOLOGY

The a/c wing can be designed by using appropriate data's. This designed model will obtain by using CATIA V5 software. Designed wing will be meshed by using ANSYS software. After that to determine the modes of vibration and structural analysis. The research problem was to identify the most critical natural modes of vibration of the aircraft wing and design a suitable piezo-actuator ''patch'' layout capable of reducing vibration. The first step is to calibrate the finite element model to existing data. Then the tuned model was analyzing to determine strain energy profiles for the first six mode shapes. The modes most critical for active control were determined through a flutter analysis of the model using ANSYS software in conjunction with existing flight test data detailing stress, strain as well as are view of the structural detail of conventional a/c wing. Next step to find maximum or average value from this six modes result values. After found the maximum vibration value, to choose the appropriate actuator which suitable for suppress the fluttering? Piezo-actuators were subsequently designed for the most critical modes using ANSYS. The actuators is to be located at the maximum stress and strain deformation occurs on the wing area and also placed at the high strengthening, stiffness provides area.

3. FEM CONCEPT

This section describes the development of the basic horizontal member finite element model used throughout this research, and the integration of the piezo-actuator analogy. Prediction and analysis of the critical vibration modes required an accurate finite element model (FEM). The wings that will be used in the flight test are of the design. An a/c wing was detached from the model and used for the research and analysis to follow. The report and data which accompanied the finite element model primarily referred by consequently, if a reliable and accurate analogy can be developed to relate voltage changes to thermal changes, it can be applied to newly-defined elements used to represent piezoelectric actuators attached to the skin elements of the a/c wing. Development of the analogy begins with the basic Hooke's Law, σ = Eε, where σ is stress (force per unit area), E is the Young's modulus (force per unit area), and ε is strain (change in length per unit length). Since material strains can be produced by a change in temperature, Hooke's law for thermal stress–strain can also be written as

σ = -EαΔT, or in matrix form

$$\begin{pmatrix}\sigma x\\ \sigma y\end{pmatrix} = -\begin{bmatrix}E11 & E12\\ E21 & E22\end{bmatrix}\begin{Bmatrix}\sigma x\\ \sigma y\end{Bmatrix}\Delta T$$

In this case the piezoelectric material properties e take the place of the thermal coefficients and the electric field E, replaces the temperature, σ = -eE, or in matrix form

$$\begin{Bmatrix}\sigma x\\ \sigma y\end{Bmatrix} = -\begin{Bmatrix}e33\\ e31\end{Bmatrix}E$$

Nodes and elements are found by using this concept.

Where E – young's modulus of the selected material
σ – Stress value

e – Strain value

These numerical values are obtained by following model calculation.

4. RESULTS AND ANALYSIS

For a conventional a/c wing are designed under by cantilever beam section. By this principle the wing should be in one end fixed and other is to be free. Fixed edge is called root and free edge is known as tip. The tetrahedral elements are used to designing the a/c wing model. This may obtained by Galerkins FEM concept.To determining the vibration analysis on wing is to be more critical method. So that we calculate the structural analysis first and after to find the modal analysis. The air foil should be divided into six sections. Each section air foils having both leading edge and trailing edge.

So we assume that the a/c is soaring in the air at 20000ft (6096m) altitude. The 7000 mpa pressure force will acting on overall structure of the wing. And we selected the I- spar for connecting these rib sections. And which is only to withstand the shear strength and tensile strength. And each rib has 1.0mm thickness with their shape. And our designed model wing has 60 cm length from the root edge of the wing. Stress and strain distribution values are calculated using structural analysis. Modal analysis will give maximum modes of vibration values such as mode 1, mode 2, mode 3, mode 4, mode 5 and mode 6.

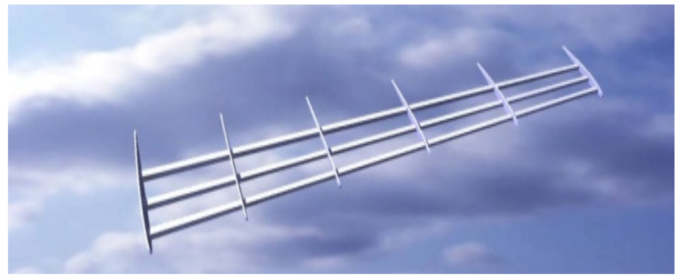

Figure 9. Wing Section Design

Desinged model has 60 cm length . Each rib has developed by 1.0mm thickness.

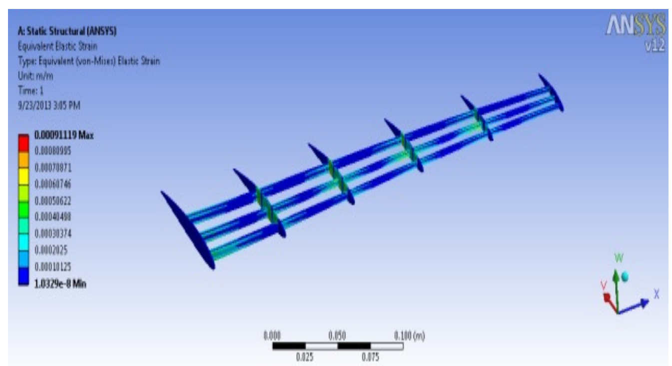

Figure 2. Strain analysis

Maximum strain : 9.1119e-004m/m
Overall pressure acting on the wing: 7000 pa

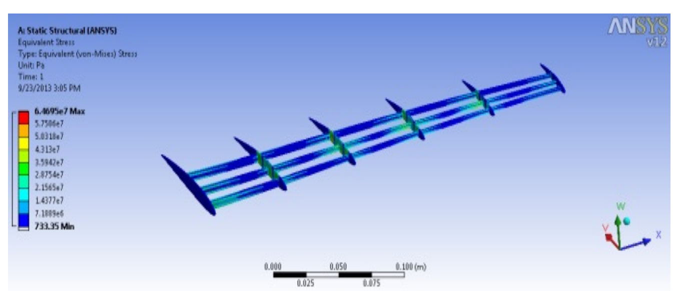

Figure 3. Stress analysis

Maximum stress: 6.4659e+007pa
Overall pressure acting on the wing: 7000 pa

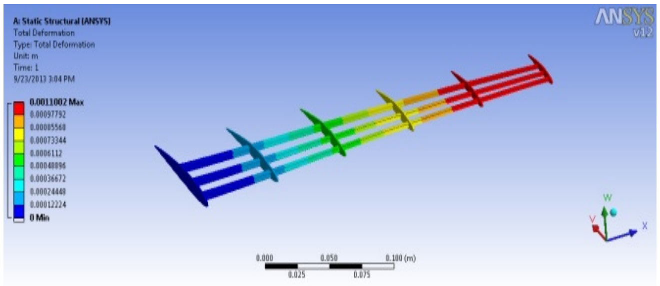

Figure 4. Total deformation

Maximum total deformation: 1.1002e+003m
Overall pressure acting on the wing: 7000 pa

For example normal force creates the 5Hz vibration on plate surface, but piezoelectric sensor might be produced 2Hz frequency range on the plate surface. From this result we satisfied the following condition. (i.e.) normal force is directly proportional to the piezoelectric force.

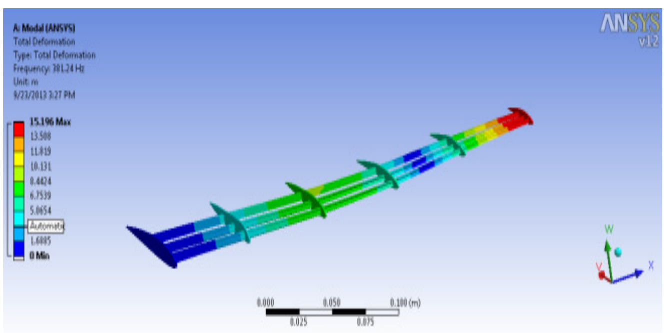

Figure 5. Vibration analysis for 5th mode at maximum frequency

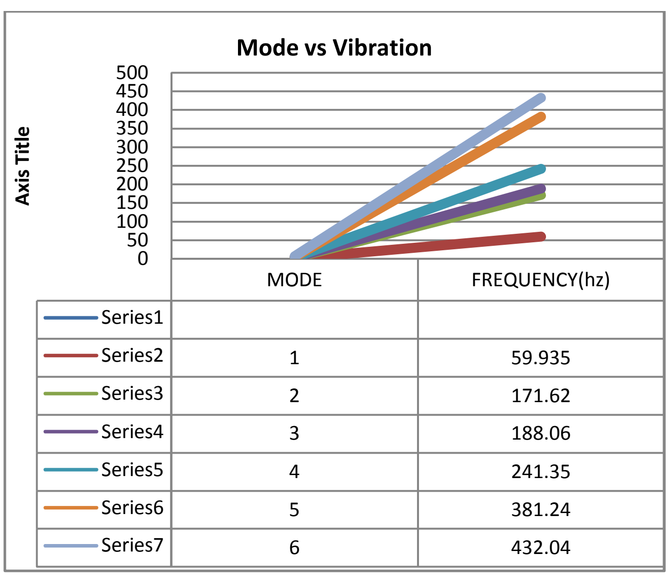

Figure 6. Mode vs Vibration

Wing Dimensions:- Piezoelectric actuator:-
Wing length: 60 cm Type: P 876.A11
Thicknes:2.8cm Dimension: (61*35*0.4)mm

Figure 7.Real Time Model with Piezoelectric Actuator

Table 2. Table for normal force

S.No	Mode	Vibration (Hz)
1	I	5
2	II	10
3	III	15
4	IV	20
5	V	25
6	VI	30
7	VII	35

So that 190gsm of glass fibre and epoxy resin was used to fabricate the wing. To fix the actuator to the entire surface of the plate area and to gives the electric field through the wire connection. While manually creates the vibration on the plate surface, it will starts fluttering and this may indicated through as normal force.

Table 1. Table for piezoelectric

S.No.	Mode	Vibration (Hz)
1	I	3
2	II	8
3	III	13
4	IV	17
5	V	21
6	VI	25
7	VII	30

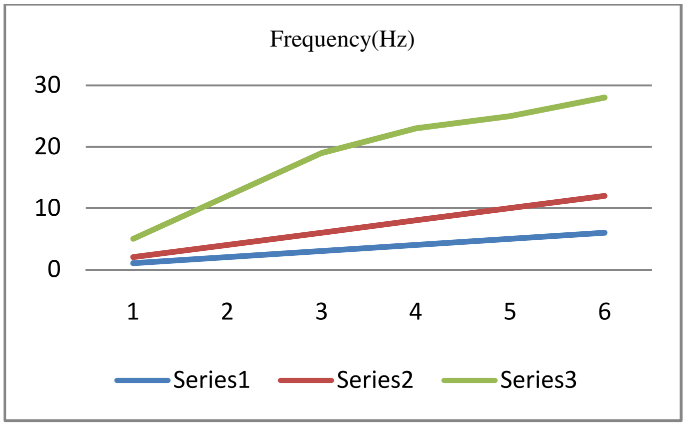

Figure 8.Mode vs vibration

From these results, thus we proved the structural life of wing would be increased without any affecting of structural damage. So that finally we suppressed the vibration on wing from natural frequency by using of piezoelectric actuator.

5. CONCLUSION

The fluttering or deformation takes placed under formation of stress and strain distribution over the entire wing surfaces. From this vibration values we calculated maximum range of vibration on wing. The active wing with piezoelectric flight control constitutes one of the first examples where such a design has been optimized and the numerical model has been validated. So that using of piezoelectric actuator on wing mid-section, which would reduce the natural frequency and this frequency of vibration is directly proportional to the actuator vibration. As a result, the structural life of aircraft wing would be increases with decreasing of vibration acting on wing surface.

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