PIEZOELECTRIC SENSOR EMBEDDED ON THE AIRCRAFT STRUCTURE TO DETECT FRACTURE

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Abstract

Successful safe flight is always a great challenge in the aviation industry. An attempt to detect fatigue and fracture by piezoelectric sensors was made. In this report a study to develop a system which provides information about damages and deformation of an onboard aircraft using compression piezo-electric sensor embedded in glass fibre reinforced polymer (GFRP) based composite materials. A setup for the predetermination of the fracture loads is done using load cell based weighing scale that uses PIC microcontroller. This type of predetermination will be useful for the pilot to prevent structural damages that could occur on flight to the aircraft structural components due to some sudden load conditions like gust or due to over air speed.

Interest in, and utilization of, new materials and technologies is a challenge. Use of GFRPs in engineering products has steadily grown over the last three decades. General purposed commercial finite element code was employed to develop the computational model. Computational model was constructed using 3- D finite elements. For comparison purpose, compression load test was carried out the load and the specimen size as close as possible to those used in computational model. Both computational and experimental results are found to be in good agreement in terms of damage size. A simple setup to predetermine the fracture load is fabricated and a test for load condition of 4kgs. is chosen to test the setup and a successful attempt is made to show the capabilities of the setup.

Keywords — *Piezo-electric sensor, Fatigue, Fracture, Composite, Structure, SHM*

I. INTRODUCTION

Failure of an aircraft structural component can have catastrophic consequences, with resultant loss of life and the aircraft. The investigation of defects and failures in aircraft structures is, thus, of vital importance in preventing further incidents. In general, failures occur when a component or structure is no longer able to withstand the stresses imposed on it during Operation. Commonly, failures are associated with stress Concentrations, which can occur for several reasons including: Design errors, e.g. the presence of holes, notches…The microstructure of the material may contain voids, inclusions etc. Corrosive attack of the material, e.g. pitting, can also generate a local stress concentration. The process of implementing 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 in light of the inevitable aging and degradation resulting from operational environments. After extreme events, such as earthquakes or blast loading, SHM is used for rapid condition screening and aims to provide, in near real time, reliable information regarding the integrity of the structure.

The project involves experimental and computational analysis of GFRP under compression loads. Then a simple setup for predetermination of Fatigue and Fracture in GFRP has done

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II. EXPERIMENTAL ANALYSIS

In this project, the composite material is subjected to fatigue and fracture analysis using Peripheral interface Control (PIC) with embedded advanced C++ program. The material property of the glass fibre composite material is found out using compression load test.

The glass fibre composite material of dimensions 30 x 30 cm with six layers is manufactured by hand layup method. Epoxy resin is used to create bond between the layers. The figure 2.1 shows the model of the glass fibre composite.

Figure 2.1 Glass fibre reinforced composite laminate

Now the glass fibre material is tested for its compression mechanical properties using compression load test under ASTM guidelines. Under ASTM guidelines the composite material test size for compression load test is 7.5 x 6 cm, so the test material is cut down to the specified dimensions above.

Then the compression test is carried out by placing the layers of glass fibre composites on the test bed of the compression load testing machine. Load is gradually applied through the test material and the fracture point of the material is found out until the material fractures. The table below shows the load at which the fracture for the glass composite materials.

Table 2.1 Dimensions of Glass Fibre Reinforced Composite Laminate

S. No.	Material Type	Size(cm)	Load(KN)
1	Glass Fibre composite	30 x 30	2880

The figure 2.2 shows the fracture in glass fibre reinforced composite laminate that starts from the edges and then run inwards.

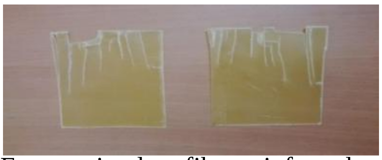


Figure 2.2 Fracture in glass fibre reinforced composite laminate

A. *Set Up For Predetermination Of Fatigue And Fracture In Glass Fibre Composite Laminate*

Block Diagram:

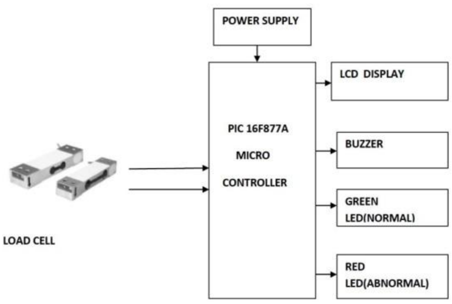


Figure 2.3 Schematic Diagram of Setup for Predetermination of Fatigue and Fracture in Glass Fibre Composite Laminate

Here The Controlling device of the whole system is a Microcontroller. The data from the load cell sensor are processed and displayed on to a LCD. Also, the Microcontroller continuously monitors the load cell output value and judges whether the product weight normal means it alerts through LED indicators otherwise abnormal means the buzzer will be on.

B. *Softwares Used*

1) PIC-C compiler for Embedded C programming.
2) MPLAB IDE v8.56
3) PIC kit 3 Programmer for dumping code into Micro controller

C. *Hardware Description*

1) Load Cell
2) PIC Microcontroller 16F877A
3) Power Supply
4) LCD Display
5) Buzzer and LED Indicators

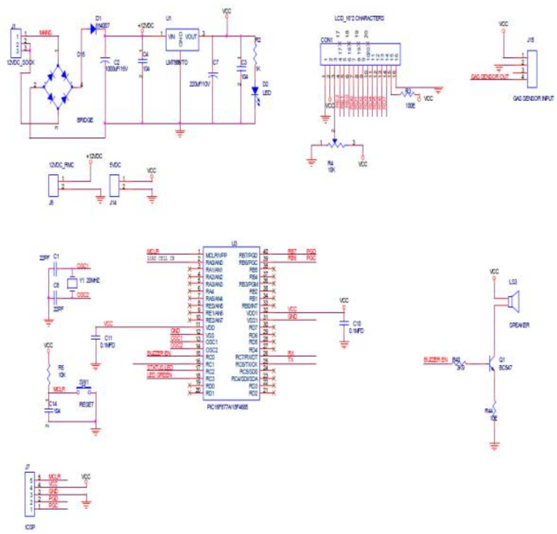


Figure 2.3 Hardware Arrangement

The developed microcontroller based electronic weighing balance has following advantages: Low-cost, flexible and portable. This system is able to measure mass in the range of 0 to 6kg. As PIC Microcontroller has inbuilt ADC, size is compact, Accuracy is more.

This can be used for

1) Load checking
2) Weight
3) Strain Gauge

D. *Setup For Predetermination Of Fatigue And Fracture In Glass Fibre Reinforced Composite Laminate*

A setup for predetermination of fatigue and fracture in glass fibre reinforced laminate is shown below in the figure. .the display will indicate the load applied to the composite material laminates and the red light indicator acts as the indicator maximum load which is coded with PIC controllers.

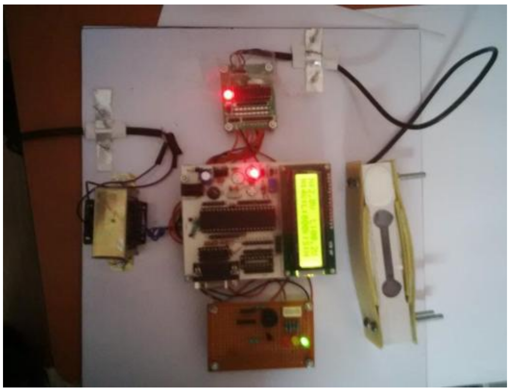


Figure 2.4 Setup for Predetermination of Fatigue and Fracture in Glass Fibre Reinforced Composite Laminate

A load cell is attached to the composite laminates that will transfer the amount of applied load on the composite laminate to the controllers.

Figure 2.5 Glass fibre reinforced composite laminate attached to a load cell

To test the setup an optimal load of 4 Kg's is set to the controllers. When the load is gradually applied on the glass fibre reinforced composite laminates from the outer surface.

As the load is applied gradually the green light indicator will glow as show in the figure.

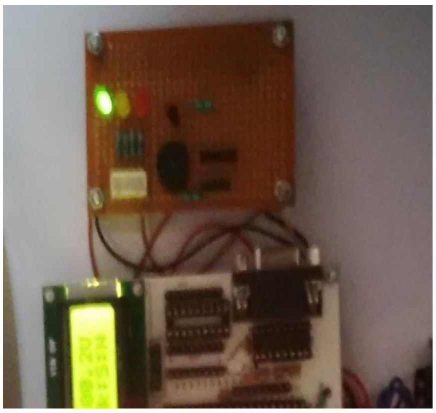


Figure 2.6 Green light indicates the applied load is below 4 Kg's.

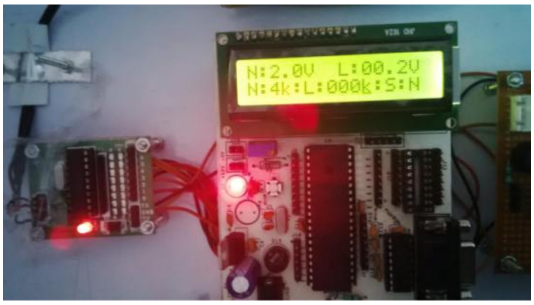


Figure 2.7 As the load reaches 4kgs. Red light indicator glows

III. CONCEPTUAL DESIGN

The experimental results are compared with the numerical analysis using ANSYS 14.0 Mechanical APDL. Modelling of the glass fibre composite laminate is done using ANSYS and the model is shown below in the figure.3.1. The glass fibre composite laminate is modelled and fabricated which is used for the experimental calculation.

Table 3.1 Dimensions of Modelled Glass fibre composite laminate

Parameter	**Dimension**
Length	30 cm
Width	30 cm
Thickness	0.5 mm per lamina

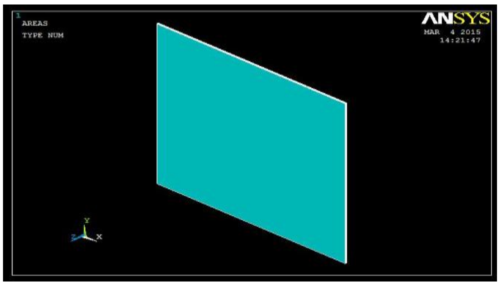


Figure 3.1 Isometric views of glass fibre composite layers

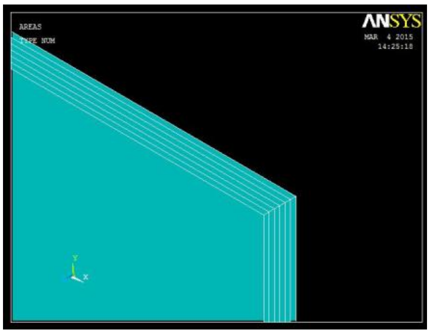


Figure 3.2 close up view of glass fibre composite layers

Table 3.2 Mechanical properties of glass fibre composite.

Young's Modulus	9.38 x 10^6
Poisson Ratio	0.23

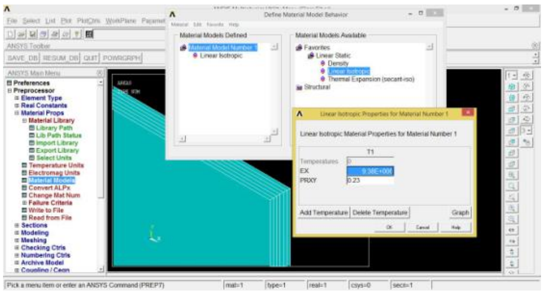


Figure 3.3 Mechanical properties of glass fibre composite.

Then the model is meshed using the meshing command from the pre-processor.

The meshed model is shown in the figure below.

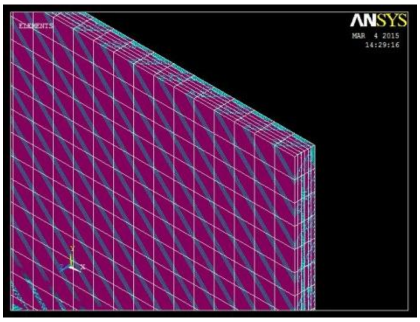


Figure 3.4 Close up view of mesh of glass fibre composite

The desired load of 2880 KN is applied as uniformly distributed load over the top surface of the glass fibre composite to simulate the compression test. The lower surface of the glass fibre composite is fixed and the degree of freedom for the lower surface is considered to be zero.

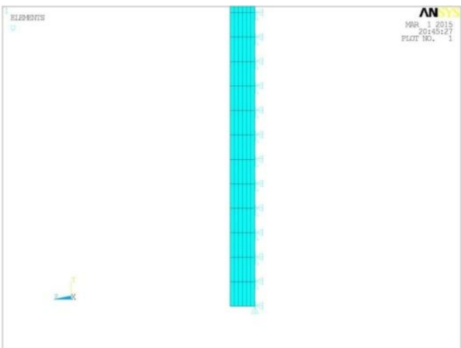


Figure 3.5 Fixed lower surface of the glass fibre composites

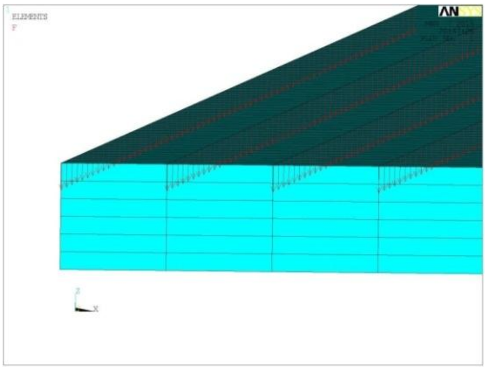
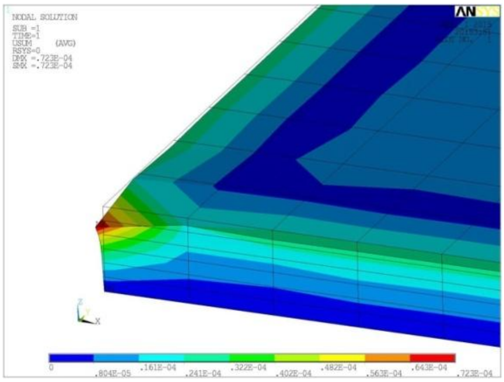


Figure 3.6 Application of Load on the upper surface of glass fibre composite

The results are calculated and plotted for the fracture point load



The above figure 3.7 shows the distribution of load on the glass fibre composite laminates. From the figure it can be found out that the maximum load is acting on the corner of the laminates and thus the fracture starts only at the corners of the laminates and then propagates to the inner part of the glass fibre laminates.

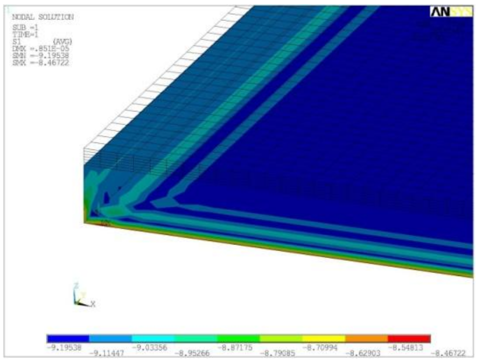


Figure 3.8 Deformation of glass fibre composites with un-deformed structure

The above figure 3.8 shows and compares the deformation of glass fibre composite laminate with un-deformed structure. Since the lower fixed and the load is applied from the upper surface, it is clear that the deformation of glass fibre composite laminate is maximum only at the upper surface

IV. RESULT AND DISCUSSION

The results from the experimental and numerical analysis of glass fibre reinforced composite subjected to fracture load are compared and discussed. A setup for the predetermination of the fracture and fatigue loads is done using load cell based weighing scale that uses PIC controller. This type of predetermination will be useful for the pilot to prevent structural damages that could occur on flight to the aircraft structural components due to some sudden load conditions like gust or due to over air speed.

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