ANALYSIS OF MATERIALS FAILURE BY USING COMPRESSION LOAD CELL

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ABSTRACT

To develop a system which provides information about damages and deformation of an onboard aircraft using compression load cell sensor array embedded in glass fiber reinforced polymer (GFRP) based composite materials. Interest in, and utilization of, FRPs in engineering products has steadily grown over the last three decades. Their high strength-to-weight ratios and rot and corrosion resistances are advantages for an increasing number of diverse applications from armory through to yachting and land transportation. Composite materials have been increasingly used in automotive engineering, aerospace development, marine technology, electronic devices, and construction industries. General purposed commercial finite element code was employed to develop the computational model. Glass fiber reinforced composite, one of the commonly used structural composites, was chosen for the test material. 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 4kg's chosen to test the setup and a successful attempt is made to show the capabilities of the setup.

Keyword: - *Reinforced polymer, Composite materials, Corrosion Resistance.*

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1. INTRODUCTION

Composite materials (or composites for short) can be defined as engineered materials made from two or more constituent materials which contain significantly different physical or chemical properties and remain separate and distinct on a macroscopic level within the finished structure. There are two types of composite, the first one is short fiber reinforced polymer and the other one is continuous fiber reinforced polymer. Glass fiber reinforced polymer or plastic is one of the example of composite material. Fiberglass is material made from extremely fine fibers of glass. The role of these fibers is as a reinforcement agent for polymer products. Fiber glass is widely used in electronic, marine and automotive industries. With the increased application of glass fiber composite in dynamic situation, knowledge of impact strength of this material is becoming important. As such, considerable amount of research has devoted to study the strength of this composite under dynamic load using computational and experimental methods.

1.1 Process of manufacturing of composite materials

Composite materials can be produced by a range of processes. These vary from the manual lay-up of reinforcement and hand application of resin to fully automated continuous processes. The most common techniques are:

- Hand or spray lamination is the most common process, accounting for over 40%of composite production worldwide. This is due to its flexibility, which allows use of all reinforcement types. The use of polyester resins dominates, but epoxy and vinyl ester resins are also used.
- Compression molding accounts for about 25% of all composites processing worldwide. It is a highly automated process in which pressure is used to force preheated resin to adopt the shape of the mold and impregnate the reinforcement. The process uses thermosetting resins and heat and pressure are applied until the resin is cured.

- Resin injection production accounts for about 5% of global FRP composite production. It can be a highly automated technique, producing smooth-sided parts and delivering low volatile organic chemical emissions.
- Pultrusion is a highly automated process suited to the production of continuous profiles such as I beams, T sections and tubing. Continuous fibers are impregnated with resin, then pulled through a shaping die and cured. Pultrusion processes are used to produce about 5% of global FRP composites.
- Vacuum infusion reduces emissions, compared to hand lamination, by employing a fully enclosed mold. Components can be exactly reproduced offering higher quality and performance.
- Prepregs, i.e. reinforcement material pre-impregnated with resin, is supplied as a sheet ready for use by the molder. Most are based on epoxy resin and carbon fiber.
- Continuous sheet production produces flat or corrugated translucent or colored profile. A layer of resin is deposited onto moving polymer film. Chopped glass fiber is then added and impregnated with resin. The resin is then cured.

1.2 Computational methods

Among the computational method, finite element method (FEM) is a widely used method due to its flexibility to model and analyze variety of engineering problems. Some popular FE packages p to date are Algor Software, ANSYS, Dyna and many more. Major advantage of FEM is we can reduce the cost of experimenting. Impact analysis is expensive whereas the material will be analyzed and it will be failed intentionally. Another than that, the analysis is a time consuming process, by using FEA method we can save a lot of valuable time and reduced losses. Based on the information and published journal found, the number of journal that related to the compression load test of fiber glass is still low. The journals found are mostly research on other composite materials such as carbon fiber and so on. With this compression load test, it will give other researchers the new information on fiber glass characteristic of the different fiber types the most economic, and therefore most commonly used, fibers are made from glass. Depending on the application this glass may be low alkali content “E-glass” or alkali resistant “AR-glass” for use in reinforcing bar for concrete. High strength glass fibers are available and are used in aerospace applications. Carbon fibers, well known from the aircraft and high performance car applications that have used them for many years, offer superior rigidity compared to glass fibers. However, this additional performance commands a higher price. Aramid fibers can be either low modulus, e.g. for energy absorption in body armor, or high modulus for aerospace applications. The structure of the reinforcement can also be varied depending on application and manufacturing method. Use of chopped glass fibers and chopped stand mats both result in randomly orientated fibers in the final product. This format is cheap, easy to use and is used in large quantities for reinforcement of deck coverings and in translucent corrugated roofing profiles. There it enhances puncture and movement resistance. Woven glass roving offer greater direction strength and can be used to increase unidirectional or bi-directional strength. Thin glass surface tissue, or scrim, can be used when a resin-rich surface is needed. Continuous fibers, oriented in a single direction, offer the ultimate properties along the axis of the fibers, but the cross-direction of the product inevitably has lower properties. Careful design of the part is, therefore, essential to make best use of this anisotropy. Matrix resins can be selected from a number of different chemistries. The choice is generally based upon the required performance and, of course, cost. Polyethylene and polypropylene are the cheapest thermoplastic resins. These materials typically find applications in composite cable applications where lightweight and reasonable environmental resistance is attractive attributes. Polyester thermosetting resin materials are also a cost conscious choice. They offer moderate environmental resistance and have been widely used in New Zealand for the production of FRP roof profiles. Epoxy resins are also thermosetting, but cost about twice as much as polyester resins. They are perceived to offer superior environmental resistance. Polyurethane thermoplastic resins offer even better environmental resistance, but also cost about twice as much as polyester-based composites. They find applications in aggressive environments, such as chemical plants, where they are used to substitute for metals. Phenolic-based thermoset systems have cornered the off-shore platform market. Good resistance to fire and the highly saline environment have driven this trend. Phenolic materials are also cost competitive with polyester materials, which implies that they have potential for wider use in construction. The paper has focused in the areas of glass fiber composite reinforced materials under compression load. The glass fiber is fabricated and subjected to a periodically sampled dynamic stress and the structural health is monitored, thus detecting the failure earlier. A compression load sensor is used to measure the change in strain or force by converting them to an electrical charge. A compression load sensor use property that by occurring any vibrations or movement of particles of materials within it generate an electric current.

2. METHODOLOGY AND MODELLING

2.1 Experimental Analysis

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 fiber composite material is found out using compression load test. The glass fiber 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.1 shows the model of the glass fiber composite. Now the glass fiber 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 fiber 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.

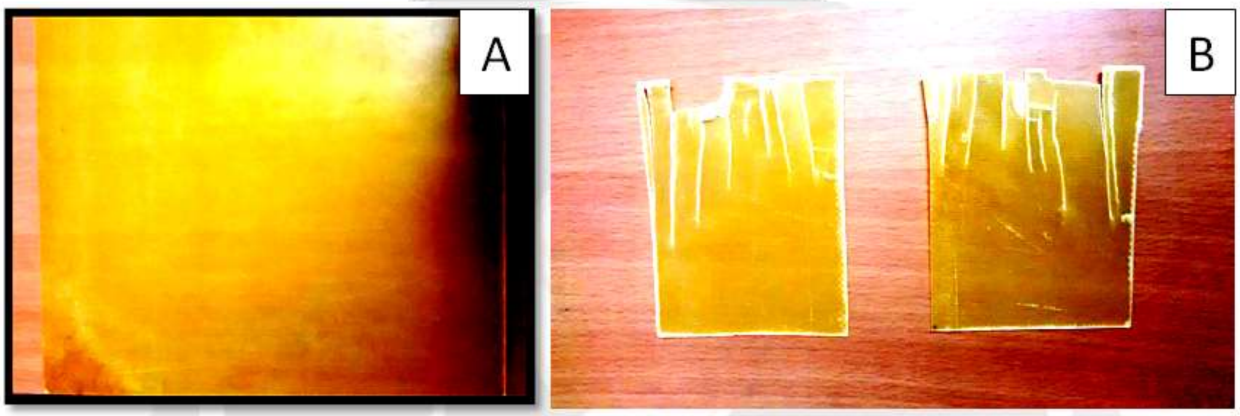

Fig - 1: (A) Glass fiber reinforced composite laminate (B) 2Fracture in glass fiber reinforced composite laminate

Table 1 Dimensions of Glass Fiber Reinforced Composite Laminate

S. No.	Material Type	Size (cm)	Fracture Point Load (kN)
1	Glass Fiber composite	30 x 30	2880

The figure.1 (B) shows the fracture in glass fiber reinforced composite laminate that starts from the edges and then run inwards. The above results are compared with the numerical analysis using ANSYS 14.0 Mechanical APDL.

2.2 Numerical Analysis

Various phenomena treated in science and engineering are often described in terms of differential equations formulated by using their continuum mechanics models. Solving differential equations under various conditions such as boundary or initial conditions leads to the understanding of the phenomena and can predict the future of the phenomena (determinism). Exact solutions for differential equations, however, are generally difficult to obtain. Numerical methods are adopted to obtain approximate solutions for differential equations. ANSYS is a general-purpose finite-element modeling package for numerically solving a wide variety of mechanical problems. These problems include static/ dynamic, structural analysis (both linear and nonlinear), heat transfer, and fluid problems, as well as acoustic and electromagnetic problems. The numerical analysis in ANSYS Mechanical APDL involves the following steps.

(i) Modeling
(ii) Preprocessing
(iii) Setup Post and (iv) processing

2.3Modelling

Modeling of the glass fiber composite laminate is done using ANSYS and the model is shown below in the figure.3. The glass fiber composite laminate is modelled after the specimen which is used for the experimental calculation.

Table.2 Dimensions of Modelled Glass fiber composite laminate

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

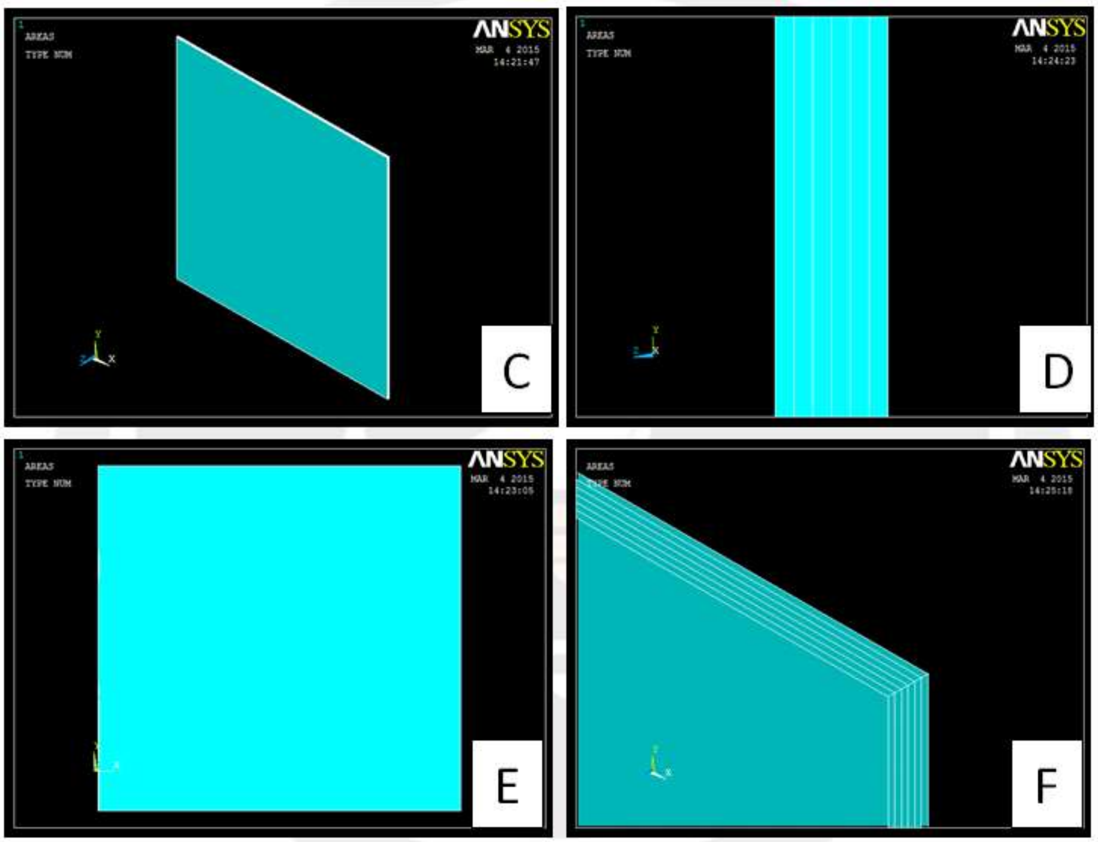

Fig - 2 (C) Isometric (D) Side (E) Front (F) Close up view of the composite layers

2.4 Preprocessing

Preprocessing involves setting up the model to structural analysis and here h-model is used. Material properties are required for most element types. Depending on the application, material properties may be linear or nonlinear, isotropic, orthotropic or anisotropic, constant temperature or temperature dependent. As with element types and real constants, each set of material properties has a material reference number. The table of material reference numbers versus material property sets is called the material table. In one analysis there may be multiple material property sets corresponding with multiple materials used in the model. Each set is identified with a unique reference number. Although material properties can be defined separately for each finite-element analysis, the ANSYS program enables storing a material property set in an archival material library file, then retrieving the set and reusing it in multiple analyses. Each material property set has its own library file. The material library files also make it possible for several users to share commonly used material property data. The mechanical properties like young's modulus and Poisson ratio are given as input to define the mechanical behavior of the glass fiber composites.

Table.3 Mechanical Properties of Glass Fiber composite laminates

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

Then the model is meshed using the meshing command from the preprocessor. A mesh is a manifold if

- Each edge closed fan is incident to only one or two faces and
- The faces incident to a vertex form a closed or an open fan.

Since meshes are usually large and complex and since many operations are performed on meshes, compact data structures that support efficient algorithms are provided.
The meshed model is shown in the figure below.

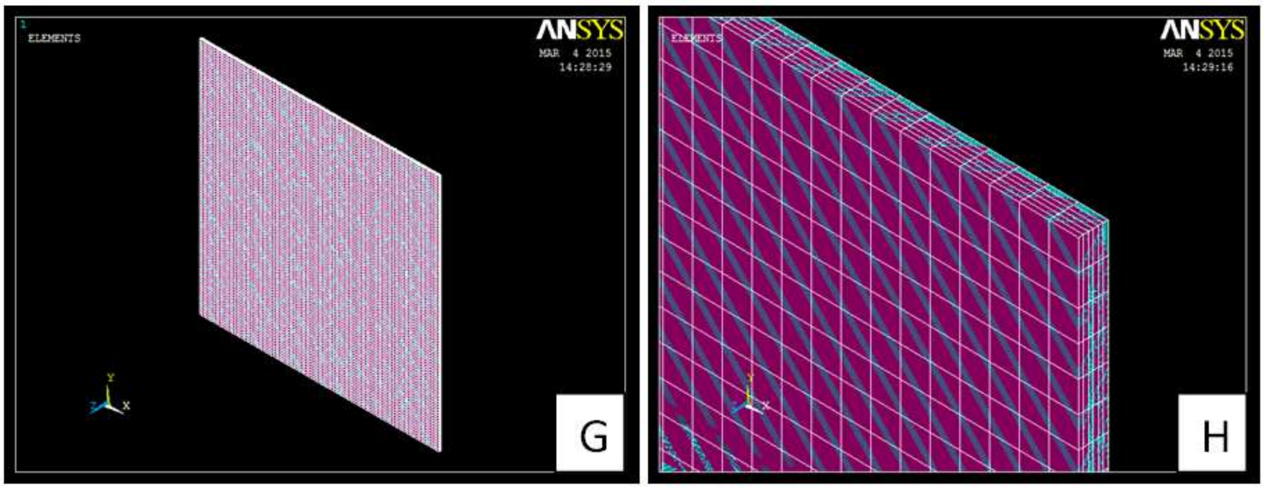

Fig - 3: (G) Meshed model (H) Close up view of mesh of glass fiber composite

2.4 Setup

It is necessary to defined the analysis type and analysis options, apply loads, specify load step options, and initiate the finite-element solution. The analysis type to be used is based on the loading conditions and the response which is wished to calculate. The desired load of 2880 kN is applied as uniformly distributed load over the top surface of the glass fiber composite to simulate the compression test. The lower surface of the glass fiber composite is fixed and the degrees of freedom for the lower surface are considered to be zero. The setup is now solved using current load setup and the results are calculated.

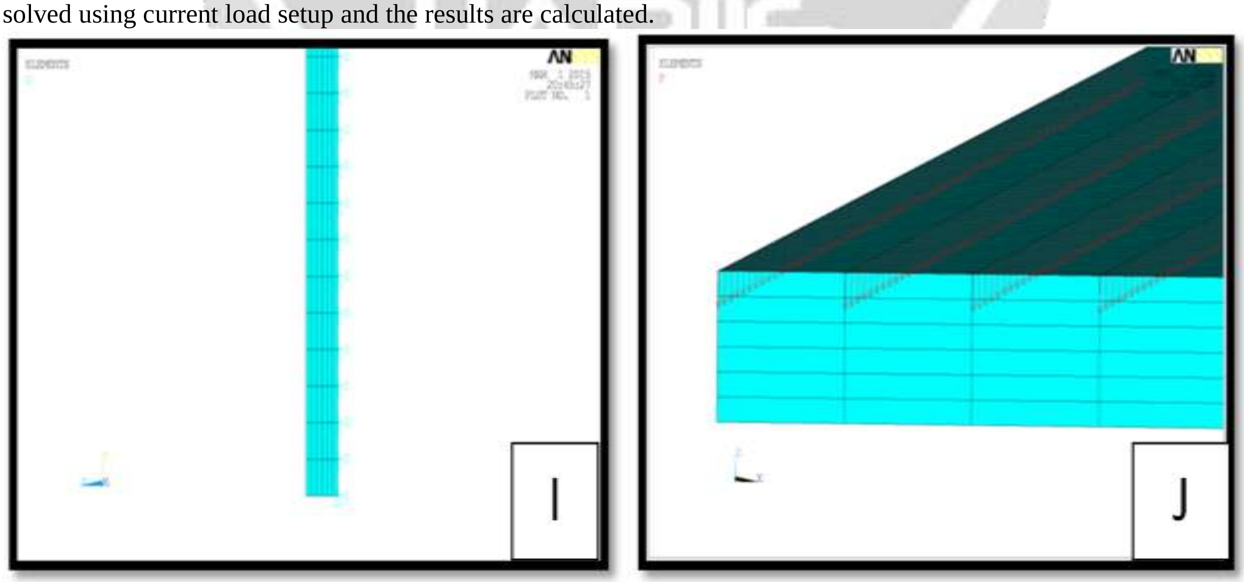

Fig - 4: (I) Fixed lower surface of the glass fiber composites (J) Application of Load on the upper surface of glass fiber composites

2.5 Post processing

The results are calculated and plotted for the fracture point load. The above figure.12 shows the distribution of load on the glass fiber 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 fiber laminates. The above figure.13 shows and compares the deformation of glass fiber 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 fiber composite laminate is maximum only at the upper surface.

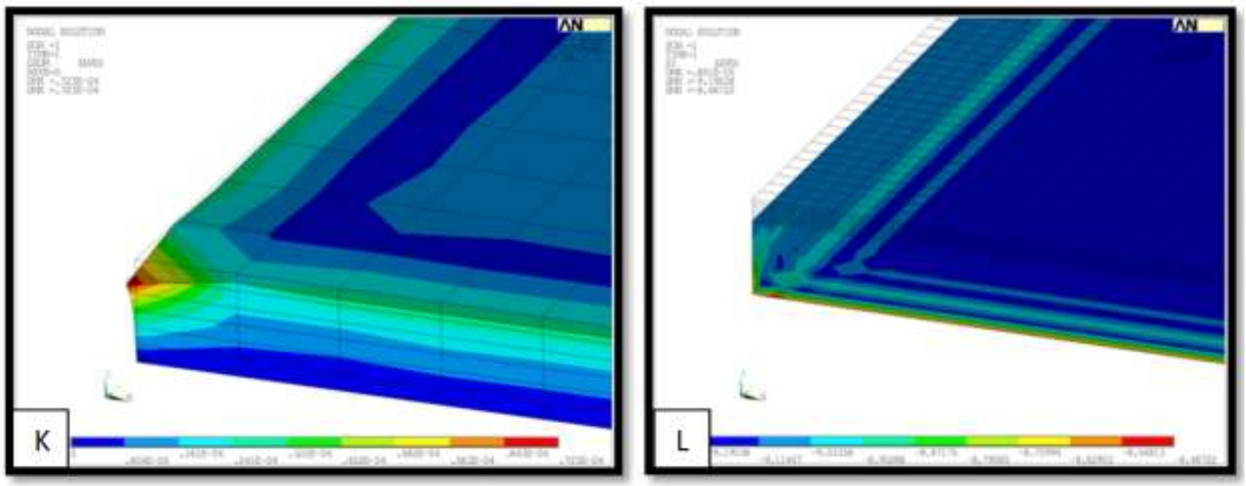

Fig - 5: (K) Distribution of Fracture point load on glass fiber composites (L) Deformation of glass fiber composites with undeformed structure

REFERENCES

[1] Adamson, T.C., Jr., and Nicholls. J.A., “On the structure of jets from Highly under expanded Nozzles into Still Air,” Journal of the Aerospace Sciences, Vol.26, No.1, Jan 1959, pp. 16-24.

[2] Back, L. H., Massier, P. F., and Gier, H. L., “Comparison of measured and predicted flows through conical supersonic nozzle, with emphasis on transonic region,” AIAA Journal, Vol. 3, No. 9, 1965, pp. 1606-1614.

[3] Belove, C. (1986), Handbook of Modern Electronics and Electrical Engineering, John Wiley and Sons Inc. U.S.A.

[4] Belove, C. (1986), Handbook of Modern Electronics and Electrical Engineering, John Wiley and Sons Inc. U.S.A., pp 2-19.

[5] Bentley, J. P., Measurement Systems, Addison Wesley Longman Ltd., UK, 2000.

[6]. Borer, J. (1991), Microprocessor in Process Control, University Press Great Britain, pp 21-30.

[7]. Braby, P. W., Electronics: A Practical Introduction, John Wiley & Sons, Canada Limited, 1983.

[8]. Brophy, J.J. (1990) Basic Electronics for Scientists, McGraw-Hill International Editions, fifth Edition, pp 462.

[9] Lewis, C. H., Jr., and Carlson, D. J., “Normal Shock Location in under expanded Gas and Gas particle Jets,” AIAA Journal, Vol 2, No.4, April 1964, pp. 776-777.

[10]. “Mechanical and Industrial Measurements”, By R. K. Jain, Khanna Publishers.

[11]. “PIC Microcontroller and Embedded Systems”, By Mazidi, Mckinlay and Causey.

[12]. Romine, G. L., “Nozzle Flow separation,” AIAA Journal, Vol. 36, No.9, Sep. 1998. Pp 1618-1625.

[13]. www.fairchildsemi.com

[14]. www.microchip.com.