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Fabrication and Analysis of Composite Panel for Rocket Motor

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ABSTRACT

A composite material is a combination of two or more different materials; it gives superior quality than its constituents. Composite materials can be used not only for structural applications, but also in various other applications such as automobiles, aerospace, marine, etc. Fiber reinforced plastic materials are widely used in various engineering industries because of their superior performance and tailor made properties. Though FRPs are widely used in various fields, they are flammable. This thesis is aimed at using composite materials in fabrication of prepress for the panels of a rocket motor to reduce the overall weight and increase the strength and stiffness of the panel along with other structural properties.

Keywords: Fabrication, Analysis, Rocket Motor, Composite Materials, Fiber Reinforced plastic, FRPs, Panels.

1.INTRODUCTION

1.1COMPOSITE MATERIALS

Composites consist of two or more materials or material phases that are combined to produce a material that has superior properties to those of its individual constituents. The constituents are combined at a macroscopic level and or not soluble in each other. The main difference between composite and an alloy are constituent materials which are insoluble in each other and the individual constituents retain those properties in the case of composites, where as in alloys, constituent materials are soluble in each other and forms a new material which has different properties from their constituents. Composite materials can be classified as:

- Polymer matrix composites
- Metal matrix composites
- Ceramic Matrix

The design of fiber-reinforced composites is based on the high strength and stiffness on a weight basis. Specific strength is the ratio between strength and density. Specific modulus is the ratio between modulus and density. Fiber length has a great influence on the mechanical characteristics of a material. The characteristics of the fiber reinforced Composites depend not only on the properties of the fiber, but also on the degree to which an applied load is transmitted to the fibers by the matrix phase.

All fibers can be incorporated into a matrix either in continuous lengths or in discount inuous lengths as shown in the Fig.1.1. The matrix material may be a plastic or rubber polymer, metal or Ceramic. Laminate is obtained by stacking a number of thin layers of fiber sand matrix consolidating them to the desired thickness.

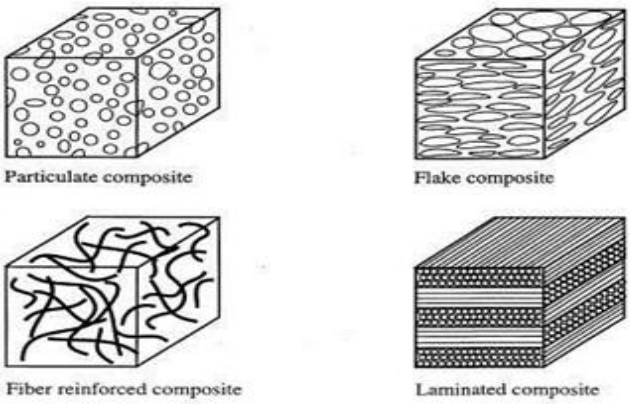

Fig1.1 Types of composites

1.2 EFFECT OF FIBER ORIENTATION IN COMPOSITES

Fiber orientation will have a dramatic effect upon the mechanical properties of a fiber-reinforced composite material. Fibers can be oriented by pultrusion or by fabricating the composite from unidirectional layers of uncured material, commonly called “prepeg”. An example of unidirectional layers is shown in figure 1.2

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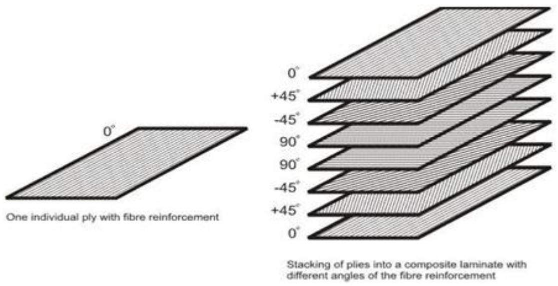

Fig1.2 Stacking Of Plies

2.LITERATURE SURVEY

Static tests were carried out on moderately anisotropic, simply supported circular plates made of graphite fiber reinforced plastic laminates of various thicknesses, loading them at the center by a hemispherical tup. A non-linear solution available for large deflections of isotropic plates was suitably modified to account for the Hertzian contact phenomena, and adopted to model the plate behavior in the elastic field. From the experimental results, an unacceptable error is made in predicting the force-deflection curve up to first failure, if the non-linear portion of the deflection is neglected. This error is more evident when thin laminates are concerned. For thick laminates, the Hertzian contact plays a significant role in affecting the plate behavior. Taking into account the local deformation and non-linearity due to large deflections, a very accurate prediction of the load-deflection was obtained. Only in the case of the thinnest composites tested, a divergence of the theoretical curve from the experimental data was observed at sufficiently high loads. The analysis of the failure modes revealed that the discrepancy is seemingly attributable to internal damage not resulting in clearly discernible discontinuities in the load-deflection curve.

3. ANALYSIS

The deflection w_{01}*of a* circular isotropic plate loaded at the center by a concentrated force p is usually calculated by the well-known strength-of-materials formula

$$w_{01} = B\frac{PR^2}{Et^3}$$

Where R is the plate radius, t its thickness, E the material elastic modulus, and B a constant *for* a given material and fixed boundary conditions.

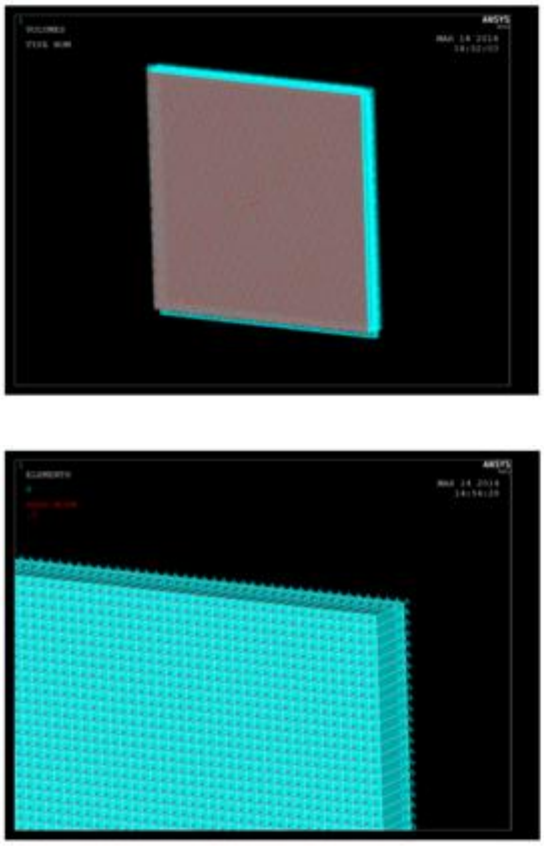

Fig 3.1: Volumes of Panel

For our purposes, it must be recalled that Eq. (1) accurately describes the structure behavior only if the deflection is sufficiently low. When this condition is no longer satisfied, the linear relationshipbetween load and deflection predicted by Eq. (1) is violated. In this case, the theory of large deflections must be addressed in order to resort to an efficient description of the phenomenon.

Even for isotropic plates, a closed-form solution to the problem of large deflections of plates does not exist. However, the following approximate formula is provided in

$$\frac{w_0}{t} + A(\frac{w_0}{t})^3 = B\frac{PR^2}{Et^4} \quad \text{-- (1)}$$

In Eq (2) where the symbol w0 has been adopted to distinguish the actual deflection from the one given by Eq. (1), A is a constant depending on the material and boundary conditions.

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From Eq (2) the deformation of the plate in the large deflection field is given by the sum of a linear and a cubic term. Of course, the former is calculated by Eq. (1) to which Eq. (2) reduces when the following relationship is satisfied:

$A(\frac{w_0}{t})^3 \ll \frac{w_0}{t}$ -- (2)

Therefore, the achievement of the large deflection regime is determined by the ratio wo/t and by the boundary conditions and material, through the constant A.

Hereafter, the case of a simply supported plate will be developed. In this occurrence

$B = \frac{3(3=\nu)(1-\nu)}{4\pi}$ -- (3)

From which it is seen that this constant is dependent on the material uniquely through the Poisson's ratio, v.in fact, the same happens for A. However, the latter constant is largely affected also by the possibility of a radial displacement at the boundary:

for instance, in the case v=0.3, A=0.272 if the edges are free to move, whereas A=1.430 for immovable than when they are free to move: the error is the same for both movable and immovable edges, provided the corresponding deflections comply with the ratio 0.272/1.430.

Putting A=1.430 in Eq. (3) it is easily verified that

$A(\frac{w_0}{t})^3 \cong 0.05\frac{w_0}{t}$

For wo/t=0.19. Consequently, assuming a linear behavior for a simply supported plate with immovable edges and v=0.3 approximately results in a 5%maximum error until the deflection is within 19%of the plate thickness. In a real case, the error will be even lower, because, despite the friction phenomena occurring at the periphery, some radial displacement will take place anyhow.

The solution of the problem under concern is much more complicated for an anisotropic plate, such as a composite laminate. Nevertheless, it can be hoped that the general form of Eq. (2) can be retained yet, at least if the flexural anisotropy is not too high. Of course, experimental evidence is needed to support this statement.

In performing both static and impact tests on composite plates, the tup displacement is often assumed as a measure of the plate deflection. In this case, at the local deformation due to the other phenomenon must be accounted for, further complicating the analysis: the local deformation due to the contact between the indentor and the plate surface.

Of course, the overall **of** displacement the tup, w_t, will be then given b**y:**

$$w_t = w_0 + w_i$$

In the field of small deflections,

$w_t = B\frac{PR^2}{Et^3} + (\frac{P}{k_i})^{\frac{2}{3}}$Is obtained

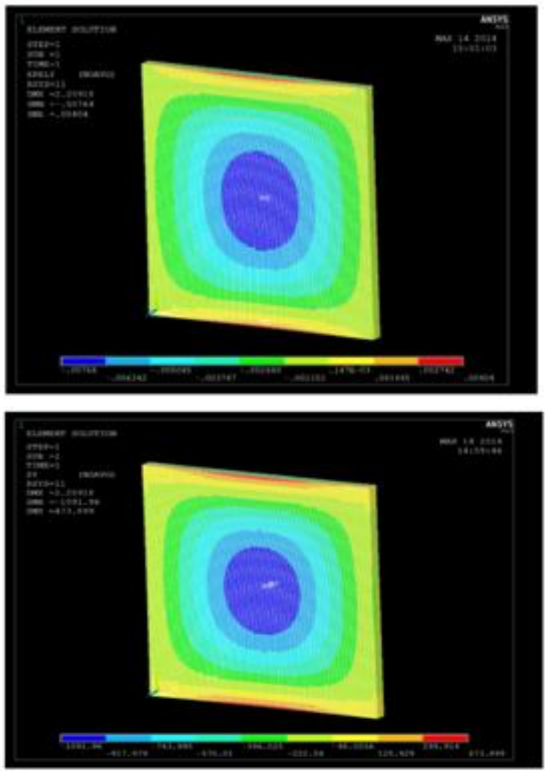

Fig 3.2: Elemental Strain in Y

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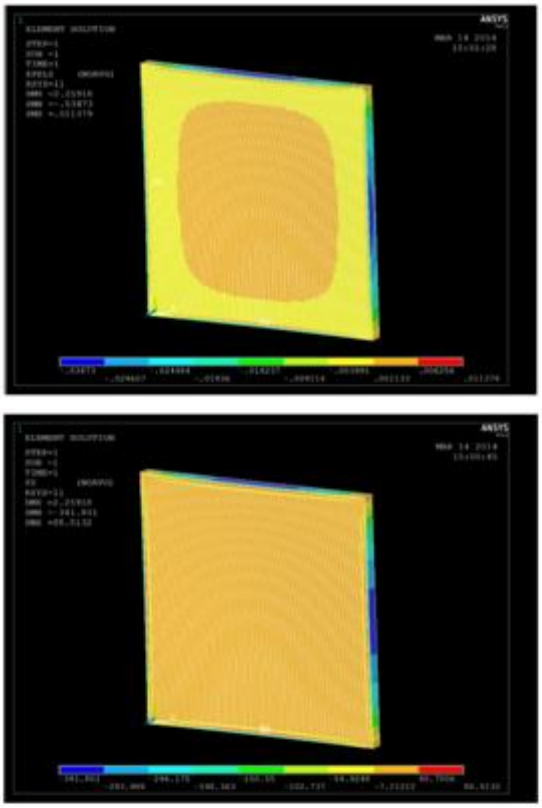

Fig 3.3: Elemental Strain in Z

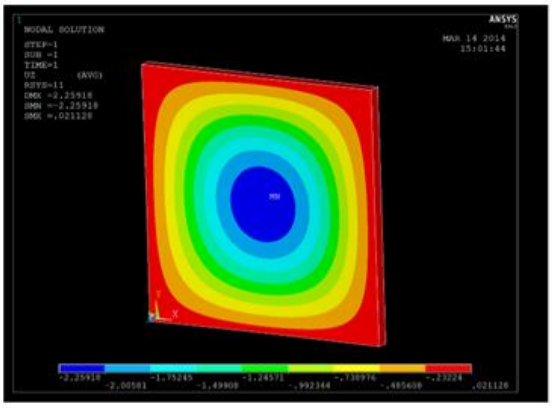

Fig 3.4: Displacement of the Panel

4.MATERIALS AND EXPERIMENTAL PROCEDURES

Two basic prepeglaminae, made of T400 fibers and HMF 934 epoxy resin, were employed for the fabrication of the laminates examined in this work. In one of the layers, the fibers were under form of plain wave fabric 193 g/m2 in areal weight: in the other, the reinforcement was unidirectional, 145 g/m2 in areal weight. The fiber content by volume of the cured lamina was v_f=0.55.

Four planes having [(0, 90) n/+45n/-45n] s stacking sequence, with n=1-4, were fabricated by hand lay-up and autoclave cured at 177’cC under 0.7MPa pressure. The round brackets in the lamination sequence denote fabric laminae. The nominal thickness of the plates was 0.95, 1.90, 2.85 and 3.80 mm for n= 1-4, respectively.

From the panels, square plates 70 mm in side were cut by a diamond saw, simply supported on a steel plate having a circular opening 50 mm in diameter, and statically loaded at the center with a hemispherical steel tup, 12.5mm in diameter, using an Instron 1251 servo-hydraulic testing machine in displacement control. The displacement rate was v=1mm/min. during the tests, the deflection was evaluated by the stroke position. Some tests were stopped when sudden load drops, clearly indicating significant damage development in the specimen, were observed; others were interrupted at predetermined load levels, suitable to avoid evident damage. Four to six tests were performed for each plate thickness.

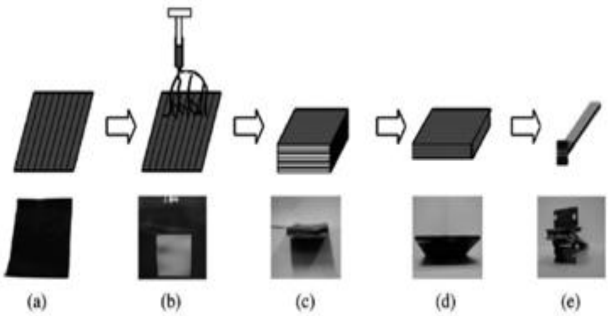

Fig 4.1: Schematic fabrication procedure

After mechanical tests, each specimen was inspected visually to ascertain eventual visible damage, and was then subjected to non-destructive evaluation using an ultrasonic C-scan apparatus. Some of the samples were also sectioned, polished, and microscopically observed by optical microscopy. The main results of those tests are out of the scope of this work, and can be found

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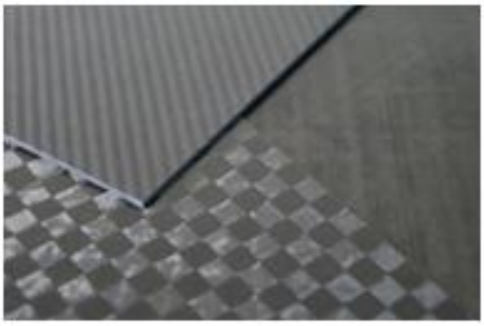
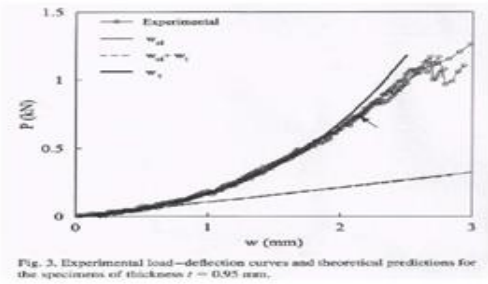


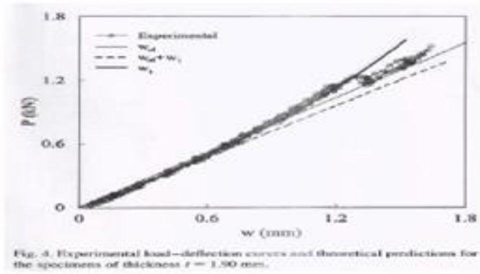
Fig 4.2: Final Prepreg

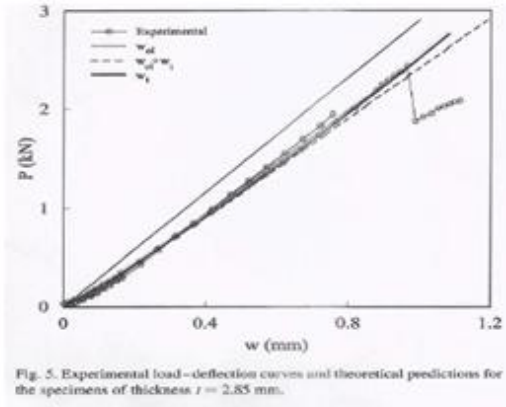
5. RESULTS AND DISCUSSION

Shows the elastic properties of the basic laminae used for the fabrication of the specimens. In order to judge the flexural anisotropy ratio of the laminates, the variation of the term D11 in the [D] stiffness matrix as a function of the in-plane direction was evaluated through lamination theory. The results are plotted in (solid line), where the quantity 12D11/t3, independent of the laminate thickness for a given lamination sequence, is shown. The angle =0 has been conventionally assumed coincident with the weft direction of the fabric laminae. From the figure, the ratio of the maximum to the minimum value of the flexural modulus is about 1.4. Therefore, the plate can be considered moderately anisotropic: this adds confidence in the possibility to model its elastic behavior through a solution valid for isotropic materials.

In fig 3-6, the load-deflection curves recorded for the plates tested are shown. In each figure, all the curves referring to a single thickness are superposed (open circles). It is evident that the scatter in the data is negligible, as expected from a carefully controlled, aeronautical grade material. Comparing figure 3 and 6, it is easily seen that, while the load-deflection curve of the thick laminates is near to linearity, the behavior of the thin composite is highly non-linear. This is expected from theory: in fact, the the first evident failure phenomenon, signaled by a 21 large load drop, is observed in fig.6 in correspondence of a deflection w_t =0.8 mm (w_t/t=0.8/3.80 = 0.21).







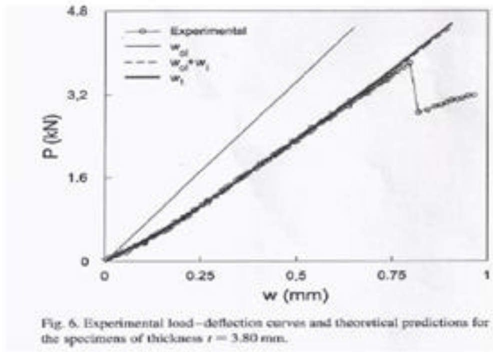


Fig. 6. Experimental load-deflection curves and theoretical predication for the specimens of thickness t=3.80mm.The load measurement. On the other hand, the upper bound (wt/t<0.15) was suggested by the need to prevent possible failure phenomena, impairing the elastic behavior of the material.

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6. CONCLUSIONS

The applicability to moderately anisotropic composite laminates of an available closed-from formula, aiming to predict the load-deflection curve so an isotropic circular plate loaded at the center in the large deflections regime, was verified. The analytic model was modified, to account for the contribution of the local deformation due to the Hertzian contact to the overall deflection. From the test results presented and discussed in this work, concerning graphite fiber reinforced plastic plates, the main conclusions are as flows.

Using the well-known strength-of-materials formulae based on the hypothesis of linearity, large errors are made in modelling the plate behavior up to the first failure point. For thin plates, the inaccuracy is mainly due to large deflections; for thick plates, the Hertzian contact plays a major role in determining the error.

Taking into account the non-linearity deriving from both large deflection and Hertzain contact, an excellent agreement is found between the experimental curves and the theoretical ones. A divergence of the letter from the actual behavior is observed only for thin plates beyond a sufficiently high load. From the study of the failure modes, this phenomenon is seemingly attributable to damage in the material, not clearly revealed by the trend of the load-deflection curve.

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