Study and Analysis of Composite Flat Plate

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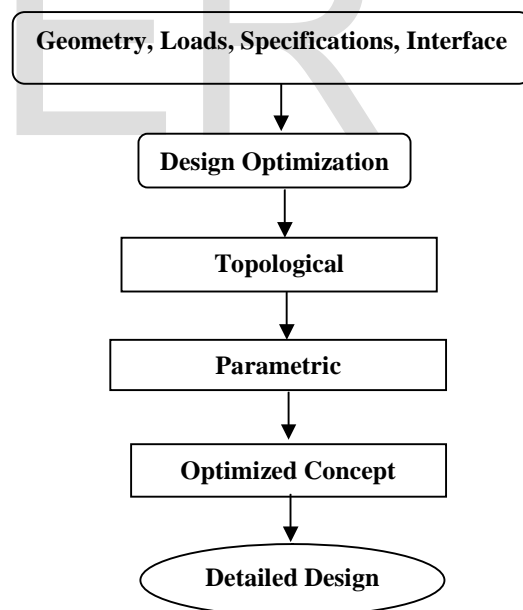Email id: arravind_r@rediffmail.com, drmsaravanan@yahoo.com, rijuvanaero09@gmail.com

Abstract - In the framework of a composite technology, a composite fabrication technique are most widely used in the aerospace and mechanical applications. Based on application of composite material, we can increase the strength of the materials and also weight can be reduced. The composite flat plate made-up of three different layers was designed with help of CATIA v5R20 software and analysis for maximum stress, strain, deformation for tensile and compressive testing condition. The layered flat was fabricated with the G926/M18 and Kelvar-49 composite material. A static test demonstrated was carried out with the application of load, in order to find out the load carrying capacity of the composite flat plate.

Keyword: Composite Flat Plate, Analysis, Delamination, Altair Hypermesh and MSC NASTRAN

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1. INTRODUCTION

The main goals of this Program were to develop innovative design and manufacturing technologies for composite components that can be used on aerospace applications. Design of composite materials requires consideration of a number of constraints based on structural performance and manufacturing considerations. Some of those structural requirements are stiffness related such as buckling performance, maximum displacements and aerodynamic smoothness. Usually strength requirements can be met by achieving the required stiffness. From a manufacturing point of view; and for unitized construction; the number of internal mandrels required to produce the control surface can usually yield a relative cost comparison between different structural lay-outs. Standard design methodology operates on the assumption of an internal configuration at the conceptual design stage followed by analysis. This result be very useful for designing and fabrication of aerospace structures and also automobile industries. In aerospace industries, weight reduction and increase of strength plays a Vitol role. In automobile industries, the race cars structures are now a day's made up of composite materials. So this material will be more Suitable for them. The Analysis procedure and results are discussed below.

2. METHODOLOGY

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│ Geometry, Loads, Specifications, Interface│
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        ┌───────────────────────┐
        │  Design Optimization  │
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        │      Topological      │
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        │   Optimized Concept   │
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                    ▼
          (    Detailed Design    )
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3. MATERIAL PROPERTIES

- Material   : Kevlar 49

- Density   : 0.052 lb/in^3

- Young's Modulus   : 16.3×10^6 psi

- Poisson's ratio   : 0.36

- Material   : G926/M18

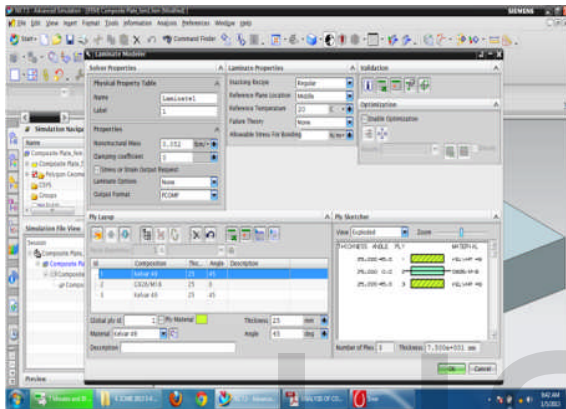- Young's Modulus   : 7E+4 MPa

- Poisson's ratio   : 0.04

Fig.1.1 Composite Plate with Three layers

4. PROCEDURE

1. Define Geometry: First of all, we have to define the geometry and dimension for the composite flat plate. With the help of obtained geometry, we have to design 3D model of the plate with the help of CAD Package softwares like Pro/E, Catia and NX CAD. After model has been designed, we have to save the modeled design in the common format like IGES or STEP.
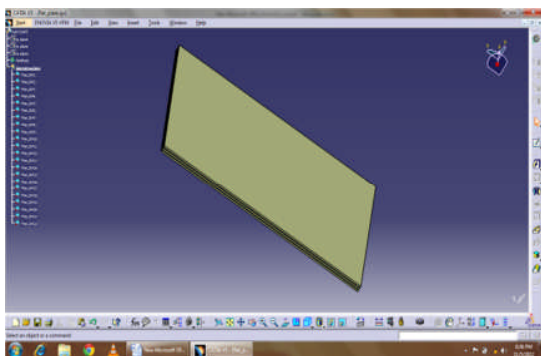

Fig.1.2 Geometry

2. For Analysis of plate, here we are using MSC Nastran software

3. Meshing has been done for the designed model, here we used tetrahydral element type for dividing the model into small number of elements

Element type	
Method of Mesh control	Quads
Size	5 mm
Statistics	
No. of Nodes	112500
No. of Elements	28125

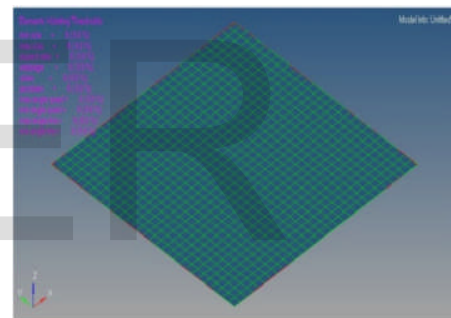**Fig.1.4 Mesh**

Code taken from Nastran Input Deck:

901- FORCE 2   35   0   1.   0.   0.   -10.

902- FORCE 2   36   0   1.   0.   0.   -10.

903- FORCE 2   37   0   1.   0.   0.   -10.

904- FORCE 2   38   0   1.   0.   0.   -10.

905- FORCE 2   39   0   1.   0.   0.   -10.

906- FORCE 2   40   0   1.   0.   0.   -10.

907- FORCE 2   41   0   1.   0.   0.   -10.

908- FORCE 2   42   0   1.   0.   0.   -10.

909- FORCE 2   43   0   1.   0.   0.   -10.

910- FORCE 2   44   0   1.   0.   0.   -10.

911- FORCE 2   45   0   1.   0.   0.   -10.

912- FORCE 2   46   0   1.   0.   0.   -10.

913- FORCE 2   47   0   1.   0.   0.   -10.

914- FORCE 2   48   0   1.   0.   0.   -10.

915- FORCE 2   49   0   1.   0.   0.   -10.

916- FORCE 2   50   0   1.   0.   0.   -10.

917- FORCE 2   51   0   1.   0.   0.   -10.

918- FORCE 2   52   0   1.   0.   0.   -10.

919- FORCE 2   53   0   1.   0.   0.   -10.

920- FORCE 2   54   0   1.   0.   0.   -10.

921- FORCE 2   55   0   1.   0.   0.   -10.

922- FORCE 2   56   0   1.   0.   0.   -10.

923- FORCE 2   57   0   1.   0.   0.   -10.

924- FORCE 2   58   0   1.   0.   0.   -10.

925- FORCE 2   59   0   1.   0.   0.   -10.

926- FORCE 2   60   0   1.   0.   0.   -10.

927- FORCE 2   61   0   1.   0.   0.   -10.

928- FORCE 2   62   0   1.   0.   0.   -10.

929- FORCE 2   63   0   1.   0.   0.   -10.

930- FORCE 2   64   0   1.   0.   0.   -10.

931- FORCE 2   65   0   1.   0.   0.   -10.

4.   We have defined the fixed support and force acting on the strut. Here we use force as

100N because the load acting on the landing strut during landing will be around 75N.
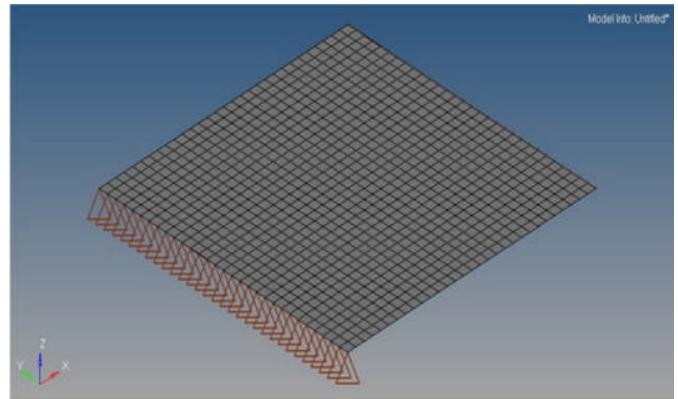

Fig.1.5 Loading

5.   Then we have to select the result what are all we need for further studies like deformation, stress and strain

5. LOADS

The design loads applied on composite plate are lift load, tensile load, compressive load and torsion load. Lift is the upward force created by the air flow as it passes over the plate, drag is the retarding force (back ward force) that limits the aircrafts speed, side load is the opposing acting in inward direction of plate and torsion load is applied when the air craft structure rotates. Table 2 shows general design loads considered to test the composite flat palte.
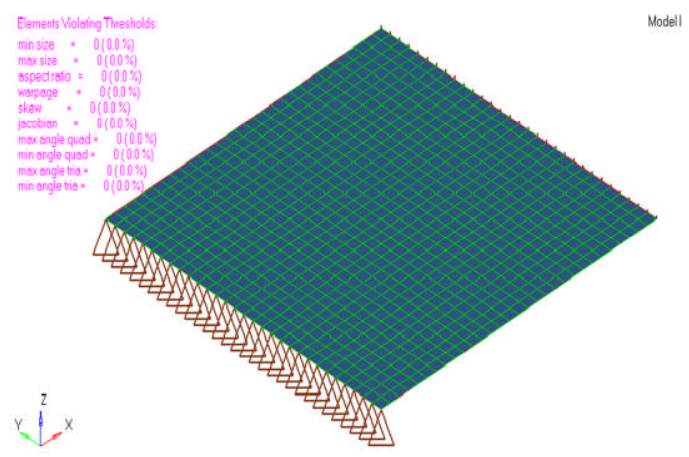
Fig.1.6 Loading and Fixed Support

1: Composite Flat Plate (Design Loads)

Type of Load	Value
Load	10 N

With the above all specifications the model was designed in CATIA (Ver-5), meshed in HYPERMESH (Ver-12) and the results are viewed in MSC NASTRAN (Ver-12).

6. STRUCTURAL ANALYSIS

There are several types of structural analysis which play an important role in finding the structural safety under stress and deformation. From that the basic structural safety of the component can be found by analyzing the structure for static and dynamic loading conditions.

7. STATIC ANALYSIS:

A static analysis is used to calculate the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. This analysis has been done by applying static loads and results are presented for the displacements and vonmises stresses, because vonmises stress theory is the main failure theory to find the failure of the components or factor of safety in the problem.
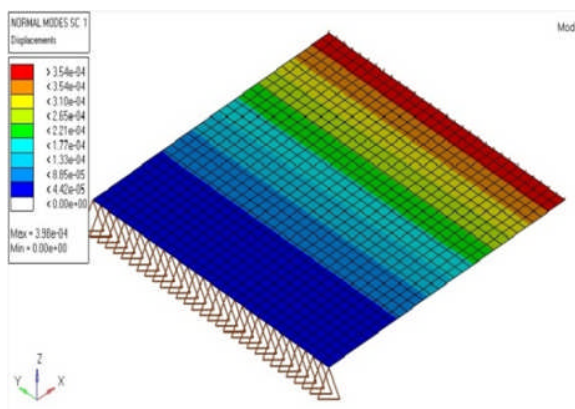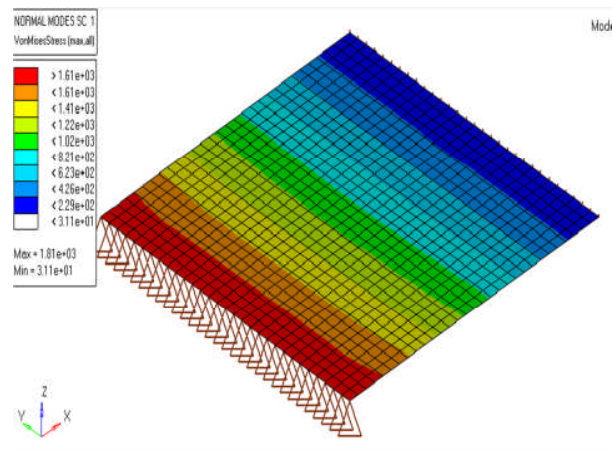

Fig.1.7 Total Deformation

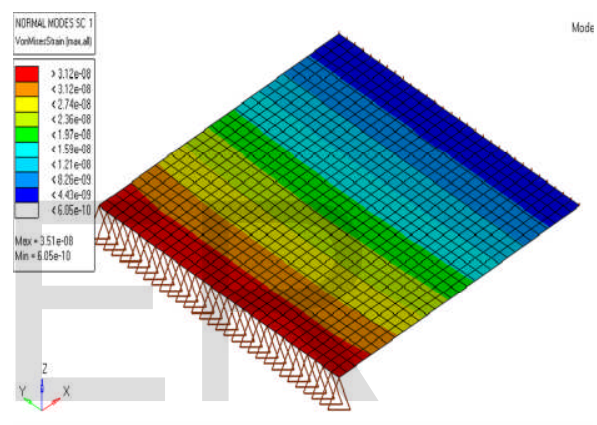**Fig 1.8 Equivalent Von-Mises Stress**

Fig 1.9 Equivalent Von-Mises Elastic Strain

From the above Contour Plots, we can able to find the place where the maximum stress, strain and deformation take place.

Results			
Plot	Deformation (m)	Strain	Stress (Pa)
Minimum	0	0	6.4805e-020
Maximum	3.98e-4 mm	3.51e-8	1.81 e+3 N/mm²

Nastran Input Deck File for case control:

```
C A S E   C O N T R O L   E C H O
COMMAND  COUNT
1"NORMAL MODES"
 6    SUBCASE    1
 7     LABEL= NORMAL MODES
```
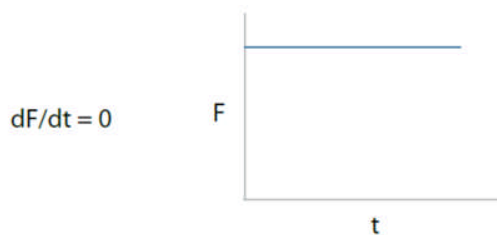
8   SPC =   1
9   LOAD =   2
10   DISPLACEMENT(PRINT,PUNCH) = ALL
11   STRAIN(PRINT,PUNCH) = ALL
12   STRESS(PRINT,PUNCH) = ALL

There are two conditions for static analysis:

1) The force is static i.e. there is no variation with respect to time (dead weight)

2) Equilibrium condition Σ forces (F_X, F_Y, F_Z)and Σ Moments (M_X, M_Y, M_Z)=0

The FE model must fulfil this condition at each and every node. The complete model summation of the external forces and moments is equal to the reaction forces and moments.

The complete equation to be solved in a linear static FE solver is $F = K * u$.

F is the vector of all applied external forces and moments.

K is the stiffness matrix of the model depending on material and geometric properties. In a linear analysis, K is constant.

u is the nodal displacement vector

8. OPTIMIZATION

Optimization is clearly one of the overall strengths of Altair and Hyperworks. You may distinguish optimization methods with respect to its position in the design phase i.e. concept design optimization such as topology, topography and free size optimization, and "fine" tuning optimization disciplines such as size or shape optimization. Alternatively, you can distinguish according to the design variable i.e. which variable of the system is modified/altered during the optimization. For

instance, the design variable of a topology optimization is the elements density, whereas in size optimization the thickness of a sheet metal may be varied

8.1 Types of Optimization

1. Geometrical Parameters
2. Shape Optimization

8.2.1 Geometrical Parameters

- Optimization for geometry parameters, work well at the individual component level rather than with complicated assemblies.

- Software cannot add or remove geometry on its own but can only play with pre defined parameters within

specified limits.

8.2..2 Shape Optimization

- Usually restricted to only linear static and normal mode dynamics.

- Good tool for innovative products (when the initial shape is not known or fixed).

- Software can give hints for the addition or removal of geometry.

8.3 CRASH ANALYSIS

1. Structural Crashworthiness Or Full Dynamic / Impact Simulations:

To find deformation, stress, and energy absorbing capacity of various structural components of a vehicle hitting a stationary or moving object. The component is said to be crashworthy (safe) if it meets the

plastic strain and energy targets .

Applications: Frontal, Side , Rear, Roof crush, car hitting a pole / wall etc.

2. Drop Test Simulations:

Drop test is a free fall test carried out to check the structural integrity of the component .

Applications : Black box of an aircraft, mobile phone, consumer goods such as TV, fridge etc

3. Occupant Safety

To find the effects of crash on the human body and making the ride safe for the driver as well as the passengers. Several regulations exist in different countries to ensure a proper certification.

e.g.: FMVSS (Federal Motor Vehicle Safety Standards) in the USA, ECE (Economic Commission of Europe) regulation in Europe. In Indiea, the ARAI has set up standard procedures for the Automobile industry and called AIS (Automotive Industry Standards)

Advantages of FEA

- Visualization
- Design cycle time
- No. of prototypes
- Testing
- Optimum design

9. CONCLUSIONS

In the framework of a composite technology, composite flat plate was designed and tested using MSC NASTRAN 2012. It is proved that composite flat plate failed beyond their Design Ultimate Load Level and also determine the maximum loading conditions for plate made up of composite G926/M18 and Kelvar-49 material. Therefore, the load carrying capability and impact loading of the composite plate was demonstrated successfully.

FUTURE SCOPE

Present dissertation work covers the design and analysis, but still it has a scope for shape optimization. All components are required corrosion protection. Corrosion control is needed for all ferrous and non ferrous materials of aircraft structures by considering:

- Coatings and/or cathodic protection

- Use of a corrosion allowance

- Inspection/monitoring of corrosion

- Control of humidity for internal zones

(Compartments)

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