A SIMPLE MODEL TO ANALYZE THE THROUGH-WIDTH DELAMINATIONS

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ABSTRACT :

In the most of the studies if not all, the composite stress analysis is made considering the unidirectional graphite/epoxy prepreg (tape). However, in the practical design, in many situations it is interesting to use the woven graphite/epoxy prepreg (cloth). Therefore, this report outlines the preliminary results in through-width delamination specimens made of graphite/epoxy prepreg tape with graphite/epoxy prepreg cloth.

Initially, a simple model based on the results presented in ref. [1] was made, analyzed and compared with MSC/NASTRAN, ref. [2]. This model considered a two-dimensional geometrically nonlinear finite element. The results obtained by MSC/NASTRAN in finite element model with 153 nodes and 128 four-node isoparametric elements were in very good accordance when compared to classical theory, presented in ref. [1]. The model contained four sub-structures with a total of 813 nodes and 740 four-node isoparametric elements.

The next step was to analyse through-width delaminations in specimen made of graphite/epoxy tape with graphite/epoxy cloth. This specimen not only contains two types of graphite/epoxy, tape and cloth, but also presents a non-symmetrical laminated. The results obtained by MSC/NASTRAN were compared with the classical theory and were found to be in very good accordance. This report shows how these results were obtained.

1. INTRODUCTION

The most of the studies about stress analysis in composite materials considers symmetric laminates. Also, regarding to the type of composite material, one can see the preference for the unidirectional composites (tape) to make the laminates.

In the aeronautical industries, this is not usual. Due to the practicability and cost, non-symmetrical laminates are used sometimes. Additionally, the unidirectional composite (tape) is used simultaneously with the cloth.

Therefore, this work makes and analysis of the through-width delaminations, exactly to explore these anomalities present in the normal working practice.

As a starting point, it was verified if the finite element model as well as MSC/NASTRAN solution were in accordance with the results presented in reference [1]. Next, a finite element model similar to the ref. [3] with some modifications in the elastic properties of the material was applied to a non-symmetrical composite made of tape and cloth. In this case, the results of the analysis according to solution 106 (non-linear static analysis) of MSC/NASTRAN are shown, along with those of the classical theory developed in the ref. [1].

2. FINITE ELEMENT MODEL

2.1 Certification of the Model

Basically the finite element model is divided in four distinct regions as shown in the Figure 1. According to ref. [3], unidirectional graphite/epoxy (regions C and D) was bonded to an aluminum bar (region A and B). The unidirectional graphite/epoxy with zero degree orientation is 0.762 mm thick and the aluminum bar is 6.00 mm thick. The finite element model contains 813 nodes and 740 four-node isoparametric elements.

2.1 Certification of the Model (cont´d)

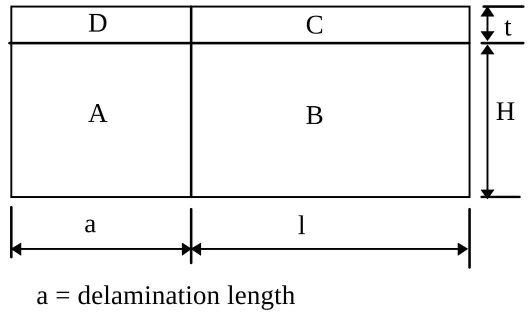

Figure 1 - Finite Element Model - Subregions Definition

The material properties were assumed to be:

Aluminum	E = 67. GPa G = 25 GPa ν = 0.33
Unidirectional Graphite/Epoxy	E1 = 140. GPa E2 = 14. GPa G = 5.9 GPa ν_{21} = 0.021

The relations between these engineering constants and the coefficients of rigidity of the material C_{ijkl} were found in the ref. [4].

The finite element model used for MSC/NASTRAN analysis has 153 nodes and 128 four-node isoparametric elements (CQUAD4) as shown in the Figure 2. In the regions A and B, MAT1 card was used with the aluminum properties. In the regions C and D, MAT2 card was used along with the coefficientes of rigidity C_{ijkl} of the unidirectional graphite/epoxy.

2.2 Model Applied to Non-Symmetrical Laminates

The results of this analysis applies to non-symmetrical laminates [LAM id 1]. For this case, the delamination length is 30.0 mm and it’s position is between the secont and the third layers from the top.

2.2 Model Applied to Non-Symmetrical Laminates (cont´d)

The real discovery of this analysis was the subdivision of the laminate, LAM id 1. The position of the delamination favored the subdivision of LAM id 1 in two laminates : LAM id 1-1 and LAM id 1-2 described as follows.

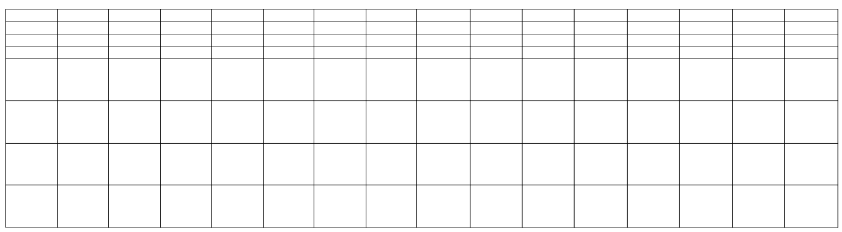

Figure 2 - MSC/NASTRAN Finite Element Model

LAM id 1 (1C90/2C45/1C90/1C45/2C90/4T0/1C45/4T0/1C90/4T0/1C45/4T0/1C90/1C45/1C90)

LAM id 1-1 (1C90/2C45/1C90)

LAM id 1-2 (1C45/2C90/4T0/1C45/4T0/1C90/4T0/1C45/4T0/1C90/1C45/1C90)

where : C is carbon/epoxy cloth and T is carbon/epoxy tape

This way, MAT1 card was used with the engineering equivalent properties, ref. [5], of LAM id 1-2, for the elements of regions A and B. For the regions A, B, C, C’, D and D’,

2.2 Model Applied to Non-Symmetrical Laminates (cont´d)

MAT2 card was used along with the material properties C_{ijkl} of LAM id 1-1. Figure 3 shows the subregions referred here.

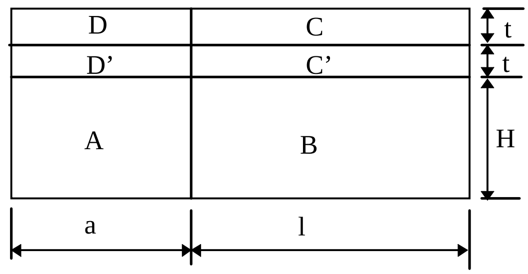

Figure 3 - Finite Element Model - New Subregions Definition

2.3 Boundary Conditions and Loading

Due to symmetry condition only half of model was necessary. The displacement along the line x_1 = -a on direction x_1 is set to zero. At x_1 = -a and x_2 = H, the displacement on direction x_2 is set to zero to prevent rigid body motion. At x_1 = l and x_2 = H, the displacement on direction x_2 is set to zero. Due to different material properties, the SPCD card was used to applied a constant loading. Figure 4, shows a schematic view of boundary conditions and loading.

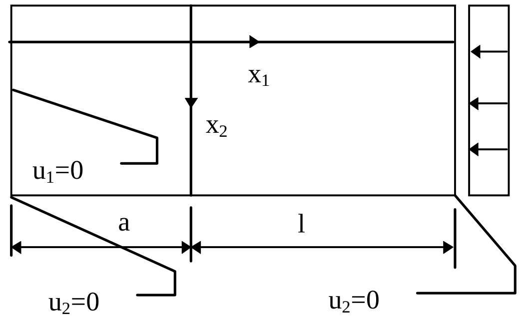

Figure 4 - Boundary Conditions and Loading

3. RESULTS AND DISCUSSIONS

Based on the results shown in Figure 5 and 6, it can be observed that the solution 106 (non linear static analysis) of MSC/NASTRAN, are very well in accordance with the classical theory presented in ref. [1]. In terms of the model and finite element analysis, we can say that the MSC/NASTRAN solution is friendly. According to ref. [3], the model needed to be refined at the extremity of delamination. Moreover, the sub-structure concepts were used to minimize the processing time.

The concept of the subdivision of the non symmetrical laminates in to the sub-laminates, applied very well for this analysis as shown by the results of Figure 7. The main advantage of this procedure is that it makes easy the re-analysis of the laminates with other layer orientation, either tape or the cloth, as it uses the concepts of the engineering equivalent properties.

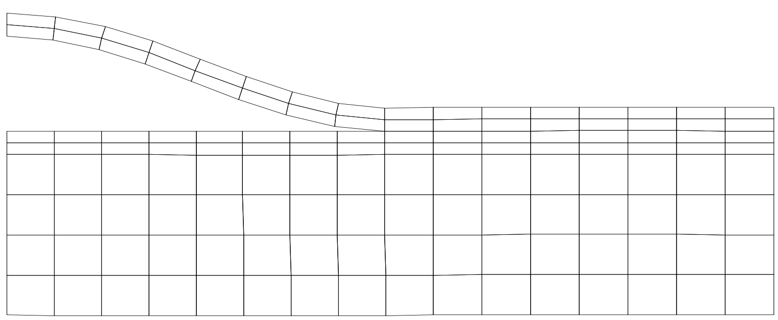

Figure 5 - Deformed Shape

3. RESULTS AND DISCUSSIONS (cont´d)

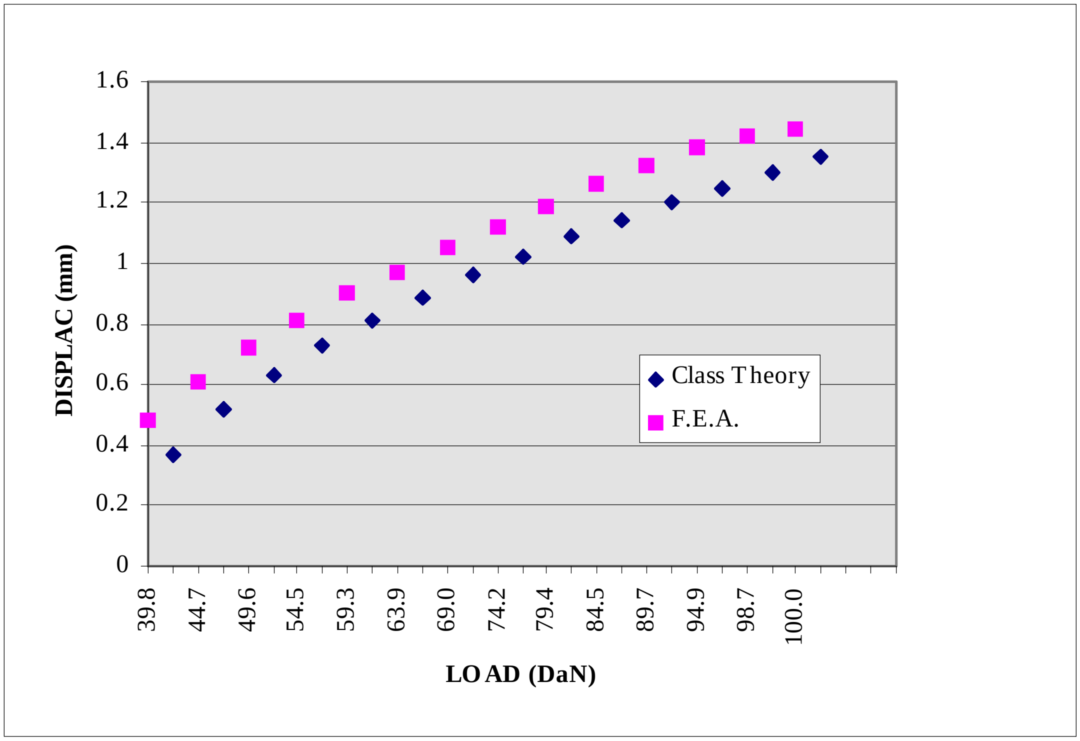

Figure 6 - Ref. [1] Classical Theory and MSC/NASTRAN Results

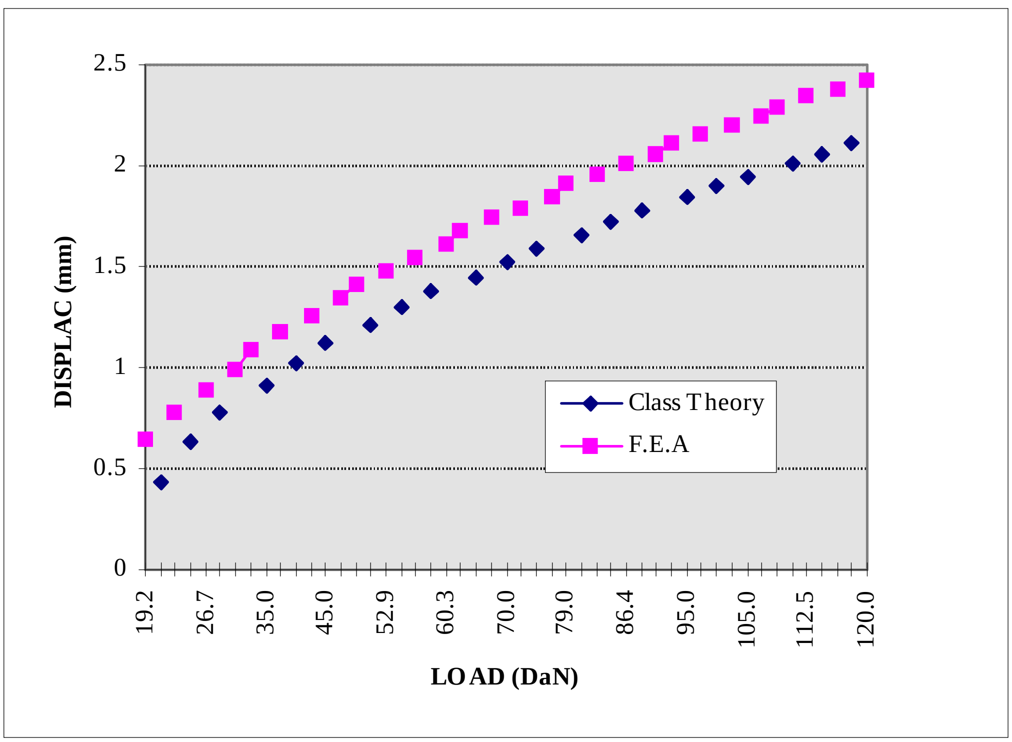

Figure 7 - Classical Theory and MSC/NASTRAN Results - Non-Symmetrical Laminate

4. ACKNOWLEDGMENTS

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