Finite Element Modelling and Buckling Analysis of Delaminated Composite Plates

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Abstract: ***Buckling behaviour of delaminated plates subjected to in-plane compressive loads has been studied by means of finite element analysis. The study shows the effect of different shapes of delamination upon the buckling response of the plate. These findings could be thus used for the evaluation of reliability of the structures such as aircraft, naval, railways etc.***

Keywords: Composite laminate, finite element, Delamination, Buckling mode

1. Introduction

Composite laminates are nowadays widely used in engineering structures due to their excellent properties such as high strength-to-weight ratio, stiffness to weight ratio, versatility in design and performance etc. One of the common mode of failure of laminated plates is delamination. The delamination is the de-bonding or separation between the individual plies of the laminate. It is considered as a serious structural degradation. Delamination arises either during manufacturing or during service. The delamination may not be visible on the surface since it is embedded within the laminate. The delamination reduces the load carrying capacity of the plates. It affects the stability and durability of the plates. Therefore it is necessary to understand the performance of delaminated plates in a dynamic environment.

2. Objectives of the Study

- To study the buckling response of the laminated composite plate containing delamination.
- To study the effect of square shaped delamination on the buckling load of the plate.
- Comparison of buckling load of the plate with and without delamination.
- The study is based on a linear finite element buckling analysis in which the contact interactions of the plate is considered.

3. Scope of the Study

- Buckling behaviour of laminated plate is studied using finite element analysis.
- The study shows the effect of square shaped delamination on the buckling response of the plate.
- In the present study, we are concerned with only first buckling load and buckling mode shape.

4. Geometry, Boundary and Loading Conditions

The laminated plate consists of woven fabric carbon epoxy plate. The size of the panel is 0.2 m x 0.2 m. The plate is considered to be made of two layers and of isotropic materials. The thickness of the layers is taken as 1.85 mm. The Young's modulus is taken as 50 GPa and Poisson's ratio as 0.3. The pattern of delamination considered is square of length 0.04m.It is located at the centre of the plate.

4.1 Boundary conditions

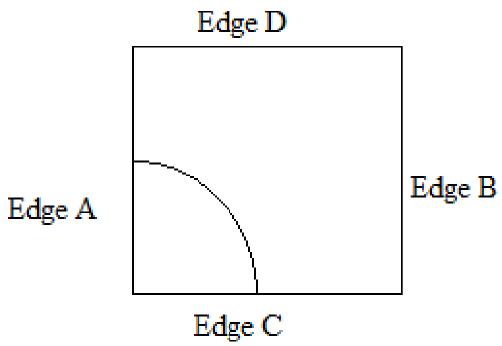

Figure 1: Boundary conditions of composite plate.

Symmetric boundary conditions are applied at edges A and C.$u_z$and $\theta_x$are suppressed on edge *B*. u_z and θ_y are suppressed on edge D.

4.2 Loading Conditions

Compressive load at edges *B* and *D*.

Finite Element Modelling

Finite element modelling of delamination buckling analysis of the plate is done using ANSYS 15.A 3-D model with 8 node shell element is used. The panel is considered to be made up of two layers and each layer is separately modelled using 8 node composite shell element. Appropriate constraints conditions are assigned to the delamination region using the contact and target facility of ANSYS. The nodes in the delamination region is left free on both the layers. Due to symmetry, one-fourth of the plate is only considered.

5.1 FEM of Laminated Plate without Delamination.

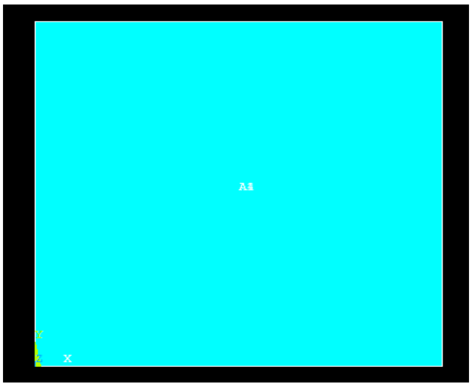

Figure 1: Geometry of the plate

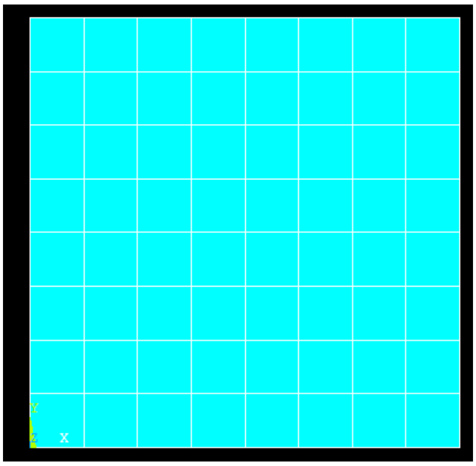

Figure 2: Meshing of plate without delamination

Figure 3: Boundary conditions of the plate

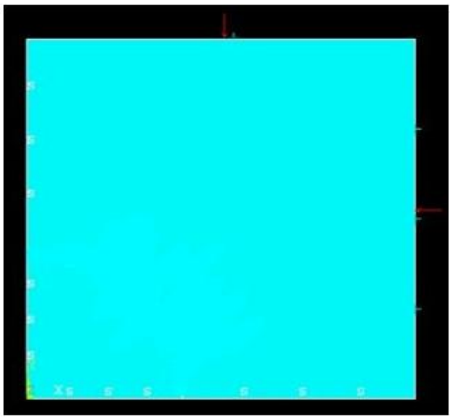

Figure 4: Loading conditions of the plate

5.2 FEM of Laminated Plate with Square Delamination

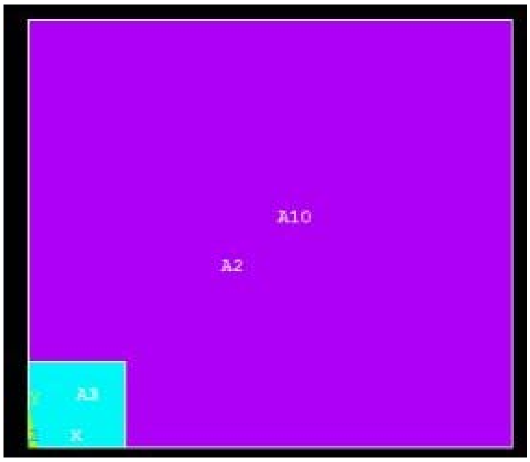

Figure 5: Geometry of the plate with delamination

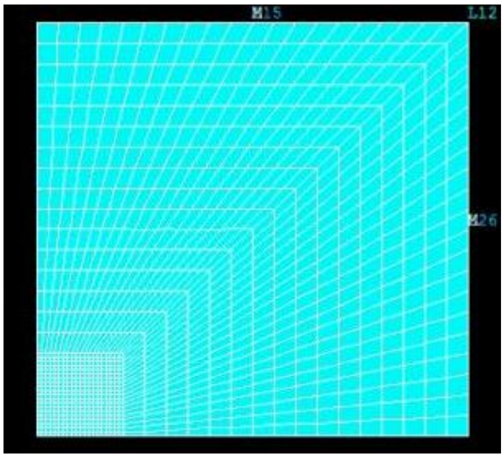

Figure 6: Meshing of plate with delamination

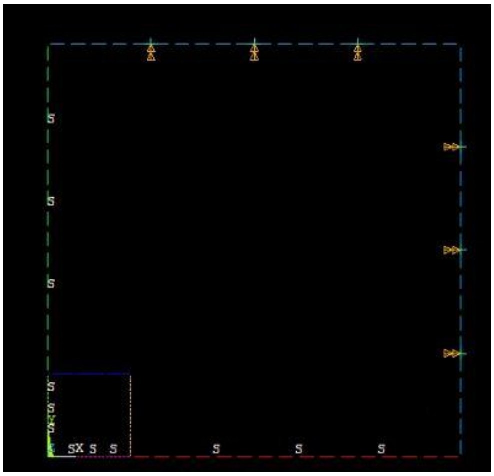

Figure 7: Boundary conditions of the plate

5. Analysis Procedure

Linear analysis of the plate is done.

1) A static analysis run with prestress effects tick on-A unit in-plane compressive load of intensity 1N/m is applied. This essentially creates the matrices for Eigen buckling analysis run.
2) Eigen buckling analysis run- This run finishes the buckling load multiplier. If unit compressive load is

applied in the first run, then the load multiplier simply represents the buckling load.

6. Analysis Results

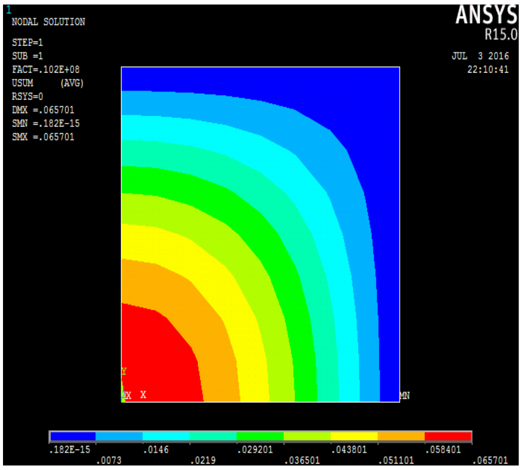

Figure 8: Buckling mode of the plate without delaminaion

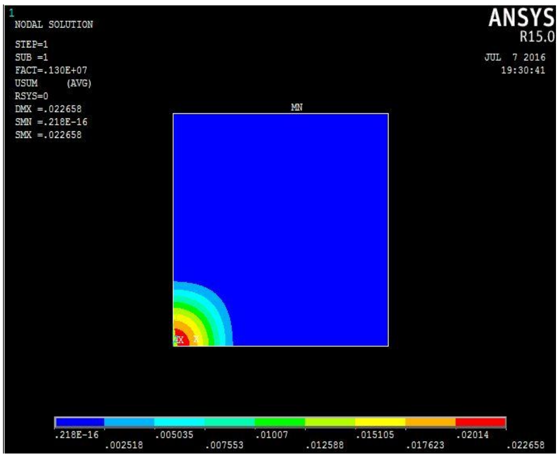

Figure 9: Buckling mode of the plate with delaminaion

7. Results and Discussions

The finite element modelling and analysis of the plate with and without delamination are done and the buckling mode shape obtained. The buckling load of the plate without delamination is obtained as 1.09×10^7N and it is the global buckling mode. But when there is delamination, the buckling load gets reduced and is obtained as 1.3×10^6N and is predominantly local. The initiation of delamination results in a greater reduction of the buckling load of plate. The difference in buckling load of the plate is 9600000 N.

8. Conclusions

1) In the present study, it is only concerned with the first buckling mode and corresponding buckling load.
2) The buckling load of the plate gets greatly reduced by the presence of delamination.
3) The reduction in the load carrying capacity of plate affects the buckling response of the plate which in turn can affect the stability and durability of the plate.

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