POST-BUCKLING ANALYSIS OF COMPOSITE PLATES CONTAINING EMBEDDED DELAMINATION WITH ARBITRARY SHAPE BY USING HIGHER ORDER SHEAR DEFORMATION THEORY

H. R. Ovesy¹, M. Taghizadeh¹*, M. Kharazi²

¹Aerospace Engineering Department and the Center of Excellence in Computational Aerospace Engineering, Amirkabir University of Technology, Tehran, Iran.
²Faculty Member of Mechanical Eng. Dept. of Sahand University of Technology, Tabriz, Iran.
* Corresponding author, e-mail: mn.taghizadeh@aut.ac.ir

Abstract
The presence of the delamination causes reductions in the bending stiffness which in turn leads to the undesirable loss in the compressive buckling and post-buckling strength. Thus, it is of chief importance to investigate the compressive behavior of composites with delaminations. Anastasiadis et al. analyzed the buckling and postbuckling behavior of delaminated composite laminates with a through the width delamination [1]. They used classical laminated plate theory (CLPT) and obtained the buckling load of the plate by solving the governing differential equations of the plate. Wang et al. have used spring simulation to determine the local buckling load of delaminated beams and plates. They have then used the developed spring simulated model to determine the strain energy release rate of the delaminated composite plates. Jane et al. analyzed the post local buckling behavior of laminated rectangular plates by implementing Rayleigh-Ritz method and using Von Karman’s nonlinear strain displacement relations [3]. In their study, the delaminated sublaminate was considered to be thin and thus the local buckling of a plate was analyzed. Andrews et al. formulated a technique by utilizing the classical laminated plate theory to study the elastic interaction of the multiple through the width delaminations in laminated plates subject to static out of plane loading while deforming in cylindrical bending [4]. Kharazi et al. have investigated the buckling of composite laminates with a through the width delamination by using different plates theories [5]. Their method, which is based on the Rayleigh-Ritz approximation technique, can handle both local buckling of the delaminated sublaminate and global buckling of the whole plate. The same method is enhanced by Ovesy et al. in order to investigate the postbuckling of composite laminates containing embedded delaminations with either rectangular or circular shape.

In the current paper, the compressive post-buckling behavior of composite laminates containing embedded delamination is investigated analytically. For modeling the embedded delamination, the laminate is divided into 4 smaller regions. The higher order shear deformation theory is implemented and the formulation is based on the Rayleigh-Ritz approximation technique by the application of the simple and complete polynomial series for each region. Solution of the nonlinear problem is based on the application of the principle of Minimum Potential Energy. Since the plate is only subjected to a progressive uniform end shortening, and there is no externally applied load, the potential energy equals to sum of the strain energies of each region. The Newton-Raphson iterative procedure is employed for solving the non-linear equations. The novelty of the presented method is that it is capable of dealing with any arbitrary shape of embedded delamination with almost no limitation. Some interesting results are obtained and compared with those achieved by the finite element method of analysis using ANSYS commercial software. The agreement between the results has been very good in general. It is noted that for a given level of accuracy in the results, ANSYS requires markedly larger number of degrees of freedom compared to that needed by the developed method. Some representative results are presented in Figs. 1.

Keywords: Composite plates, embedded delamination, higher order shear deformation, post buckling
References:


Fig. 1: Non-dimensional out of plane displacement variations of a delaminated clamped plate with single embedded delamination

$L=b=100$, $t=2$, $R1=R2=25cm$, $a1=a2=15cm$ and $U_{Xcr}'$ is the critical end-shortening Displacement corresponding to a plate without any delamination