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STOCHASTIC BUCKLING AND FAILURE ANALYSIS OF LAMINATED COMPOSITE PLATE

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ABSTRACT

The present work deals with second order statistics of first-plate failure response of geometrically nonlinear laminated composite plate subjected to compressive buckling loading with random system properties and strength parameters under random mechanical loadings. System properties such as the material properties, strength parameters and lamina plate thickness are modeled as independent random variables. The mathematical formulation is based on higher order shear deformation theory (HSDT) with von-Karman nonlinear kinematics. A efficient C^0 nonlinear finite element method based on direct iterative procedure in conjunction with a first order perturbation approach (FOPT) is developed by the authors are extended and successfully applied for failure problem in random environment and is employed to evaluate the dimensionless mean failure load by modeling the system properties as basic random variables using Tsai-Wu, Hoffman, Hashin and Lee failure criteria. Typical numerical results are presented to examine the effect of various failure criteria's, amplitude ratios, and plate side to thickness ratios, aspect ratios, boundary conditions, lamination schemes and elastic modulus ratios with random system properties and strength parametrs. It is observed that the random system properties and strength parameters have a significant influence on the nonlinear first-ply failure load and buckling response of composite plate under various boundary conditions and some new results are presented to demonstrate the applications of present work. The results obtained using present solution approach is validated with the results available in the literatures and independent Monte Carlo Simulation (MCS).

Keywords: laminated composite plate, first-ply failure loads, random system properties, buckling load, stochastic finite element method.

INTRODUCTION

Failure response of laminated composite plates that are subjected to mechanical buckling load is an important consideration in the preliminary design of contemporary, high performance aerospace vehicles and automobiles. The sizing and life estimation of many structural subcomponents of these vehicles is often determined by buckling constraints. Composite materials have been increasingly used in aerospace and automotive applications over the last three decades and have seen a dramatic increase in usage in non-aerospace products in the few years. The use of composite materials is very attractive because of their outstanding strength, stiffness, and light-weight properties. An additional advantage of using composites is the ability to tailor the stiffness and strength to specific design loads. Since most composite materials exhibit brittle failure, with little or no margin of safety through ductility as offered by many metals, the initiation of the brittle failure mechanism in composite structures must be understood and reliable prediction analysis methods need to be available. For example, laminated composite structures can develop local failures or exhibit local damage such as matrix cracks, fiber breakage, fiber-matrix debonds, and delaminations under normal operating conditions which may contribute to their failure. The ability to predict the initiation of such damage is essential for predicting the performance of composite structures and developing reliable, safe designs which exploit the advantages offered by composite materials. Hence, the need for a reliable methodology for predicting failure initiation in composite laminated structures is of great importance.

REFERENCES

[1]-S. C. Lin,T. Y. Kam, K. H. Chu. Evaluation of buckling and first-ply failure probabilities of composite laminates. Int. J. Solids Strucfurrs Vol. 35, No. 13. pp. 1395-1410, 1998.

[2]-Mark R. Gurvich and R. Byron Piped. Probabilistic analysis of multi-step failure process of a laminated composite in bending. Composites Science and Technology 55 (1995) 413-421.

[3]-S. P. Engelstad and J. N. Reddy, Probabilistic Nonlinear Finite Element Analysis of Composite Structures**.** AIAA Journal Vol. 31, No. 2, February 1993.

[4]-D. Bruno, G. Spadea and R. Zinno, First-ply failure of laminated composite plates. Theoretical and Applied Fracture Mechanics 19 (1993) 29-48.

[5]-Lambert S., Pagnacco E., Khalij A. Probabilistic model for the fatigue reliability of structures under random loadings with phase shift effects. International Journal of Fatigue 32 (2010) 463-474.

[6]-Xiaoqiang Wang, Jifeng Zhang, Zhenqing Wang, Wenyan Liang, Limin Zhou. Finite element simulation of the failure process of single fiber composites considering interface properties. Composites: Part B 45 (2013) 573-580.

[7]-Diego Cárdenas, Hugo Elizalde, Piergiovanni Marzocca, Frank Abdi, Levon Minnetyan, Oliver Probst. Progressive failure analysis of thin-walled composite structures. Composite Structures 95 (2013) 53-62.

[8]-Alp Karakoç, Jouni Freund. A statistical failure initiation model for honeycomb materials. Composite Structures 95 (2013) 154-162.

[9]-G. Catalanotti, P.P. Camanho, A.T. Marques. Three-dimensional failure criteria for fiber-reinforced laminates. Composite Structures 95 (2013) 63-79.

[10]-G.H. Erçin, P.P. Camanho, J. Xavie, G. Catalanotti, S. Mahdi, P. Linde. Size effects on the tensile and compressive failure of notched composite laminates. Composite Structures 95 (2013) 2068-79.