STOCHASTIC FAILURE ANALYSIS OF GEOMETRICALLY NONLINEAR LAMINATED COMPOSITE PLATES UNDER COMPRESSIVE LOADING

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Key words: Composite plates, Stochastic failure analysis, FEM

Summary. The objective of this paper is to examine the statistics of first ply failure load of orthotropic plate with random material properties under deterministic loading. The basic formulation is based on higher order shear deformation plate theory (HSDT) in von-Karman sense. The direct iterative based stochastic C⁰ nonlinear finite element method (DISFEM) based on first order shear deformation theory is used to predict the statistics (mean and dispersion) of first-ply failure load using Tsai-Wu and Hoffman criteria. The present approach is validated with the available results in literatures and independent Monte Carlo simulation

1 INTRODUCTION, RESULTS AND DISCUSSION

Stability and failure of composite plates subjected to in-plane mechanical loading is an important consideration in the preliminary design of aircraft and launch vehicle components. The maximum load that composite structures can support is equal to the elastically determined critical buckling load only if the stress does not exceed the proportional limit (first-ply failure) at any point in the structure prior to buckling. If the proportional limit is exceeded before instability occurs, the first ply failure of the structure will occur at a load that is smaller than the elastic critical buckling load. Failure mode of a particular composite structural plate to develop the strength prediction that could be utilized in fatigue life predictions and buckling loads

When the laminated plate is subjected to excessive in-plane compressive loadings, mechanically induced compressive stresses are developed in the constraint edges of plate. These sufficient amounts of induced compressive stresses buckle the composite plates first and consequently failure takes place. The large numbers of uncertainties are associated with manufacturing and fabrication of composite as compared to conventional materials. The complete control at each stage of these uncertainties is very difficult. The uncertainty in the material properties, which is inherent leads to uncertainties in the response behavior of the structures. For accurate analysis of structural behavior required for sensitive applications, the random variation in the material properties are incorporated in the analysis so that predicted response may not differ significantly from the observe values assuming the structures safe.

The capabilities to predict failure response and enable to better understanding and characterization of actual behavior of laminated composite plate in probabilistic sense is of prime interest to many of the researchers. In available literatures most of the work is done based on the deterministic analysis. Among them are Tolson and Zabaras [1] and Reddy [2]
et al. All the above mentioned literatures are based on complete determinacy of structures parameters, which gives only mean response and misses the deviation caused by inherent random system properties. Relatively little efforts have been made in the past by the researchers on the prediction of stochastic failure response of the structures made of laminated composite plates with random system properties. Nakayasu and Maekawa [3] evaluated the stochastic behavior of laminated composite plates using various failure criteria under the various combinations of multi-axial load conditions and lamination angles based on a general formulation for the reliability model of a unidirectional fiber reinforced laminate. Lin [4] examined the buckling failure analysis of random composite laminates subjected to random loads using the statistics of buckling strengths, the probability theories and the probability integration in the load space. Onkar et al. [5] predicted the failure load of composite plates subjected to in-plane compressive loading using SFEM based on mean-centered FOPT with basic formulation of Kirchhoff–Love plate theory. To the best of author’s knowledge, no work has been done to predict the failure load of geometrically nonlinear laminated composite plates with random system properties using stochastic finite element method based on higher order shear deformation theory [6]. This is the problems studied in the present paper.

The non-dimensionalised mean failure load, for [0/90/90/0] laminates using Tsai-Wu failure criterion is shown in Table 1 and compared with available results in literatures. From the table is shown that the present results obtained by DISFEM approach using HSDT are in good agreement with the FSDT model [2] and layer-wise plate model [5].

References

Table 1. Comparison of the mean non-dimensionalized failure load for different laminates with CCCC boundary condition Lay-ups

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<td>1.</td>
<td>0/90/90/0</td>
<td>15,483.49</td>
<td>15,440.58</td>
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