Stochastically Finite Element Buckling and Post Buckling Analysis of Laminated Composite Plates with Foundation in Thermal Environment using Micromechanical Model

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Abstract-This Paper presents the effect of random system properties on thermal buckling response of laminated composite plate using micromechanical approach. The system properties such as thermo-material properties, fiber volume fractions of respective fiber and matrix constituents and foundation parameters are modeled as independent random variables. The temperature field considered to be uniform temperature distributions over the plate surface and through the plate thickness. The material properties of the composite are affected by the variation of temperatures and based on micromechanical model. The basic formulation is based on higher order shear deformation plate theory and general von-Karman types of nonlinearity. A direct iterative based C^0 nonlinear finite element method in conjunction mean centered first order perturbation technique is out lined and solved the stochastic linear generalized Eigen value problem. The developed stochastic procedure is usefully used for thermally induced problem based on micromechanical approach with a reasonable accuracy. Parametric studies are carried out to see the effect of volume fractions, amplitude ratios, temperature increments, temperature distributions geometric parameters, lay-ups, boundary conditions and foundation parameters on the mean and variance of plate frequency. The present outlined approach has been validated with those available results in literatures.

Keywords- *Composite plate, Thermal buckling, Micromechanical Modal, Matlab, SFEM.*

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I. INTRODUCTION

Laminated composite plates are increasingly used as critical structural members in aerospace and many other applications due to gaining wide popularity as light weight components, ability to tailor structural properties through appropriate lamination scheme for achieving high strength and stiffness to weight ratio and durability and corrosion resistant characteristics combined with low density, make it more attractive compared to conventional materials.

Composites resting on elastic foundation which are used in aerospace as operation activities of large transport aircraft runways, launching pads of missile, tops and guns, Mechanical as machine beds, railways tracks and dampers, Civil as footing, mat and raft foundation, building activities of cold region, foundation of deep wells, bridges structures, nuclear and petrochemical industries etc., in severe conditions of environments the nonlinear vibration of these structures are occurred. In order to obtain effective design of the laminated composite plate the study of nonlinear vibration is most important as this plays a key role in designing of resonant free structural components. Therefore this topic has attracted much interest from many researchers.

Due to involvement of large number of parameters associated with manufacturing and fabrication of the composite structural components the complete control of each parameter is very difficult and hence the variations in lamina system properties are inherent in nature.

Apart from this, the uncertainties in modeling and determination of foundation are also inherent in nature because the foundation parameters are also depends on system properties. In practice, the present of uncertainty in the system parameters finally results in dispersion in the nonlinear response behavior of the structures. Therefore for accurate prediction of the structural response for reliable design especially in sensitive applications the lamina mechanical properties and foundation parameters are modeled as independent basic random variables in the present analysis.

The mechanical properties of composite materials depend on a wide variety of variables at the micro-level, for the example, the fiber and matrix material properties; and fabrication variables at all stages of the fabrication process, such as fiber volume ratio, misalignment of ply orientation, fiber waviness or undulation, intramina voids, incomplete curing of resin, excess resin between plies and variation in ply thickness. These variables are statistical in nature

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because they cannot measure accurately. The existing uncertain variations in system parameters may have significant effects on structural parameters, therefore mechanical properties of the composite material should be quantify probabilistically. Probabilistic analysis provides a tool for incorporating structural modeling uncertainties in the analysis of structural response like frequency response, for the accurate prediction of structural behavior for safe and reliable design.

Any stochastic problem can be split into: (a) one set of mean problem based on deterministic analysis, and (b) R set of random problems based on probabilistic analysis. These can be solved separately to determine the mean and the variance of the response of our interest. Here R denotes the number of primary random variables chosen for the analysis at the micro-level.

The basic formulation is based on higher order shear deformation theory with von-Karman nonlinearity using micro-mechanical approach. A direct iterative based C^0 nonlinear finite element method in conjunction with first order Taylor series based perturbation technique i.e., DISFEM is used to evaluate the second order statistics (mean and variance) of fundamental frequency of laminated composite plates resting on elastic foundation.

The validation of the present approach is performed by comparing the results with those reported in the literatures and independent Monte Carlo simulation. The statistics of the fundamental frequency is determined by considering uncertainties in the effective micro-level material properties of composite laminates. Typical results for second order statistics of fundamental frequency of geometrically nonlinear laminated plate with random system properties taking effects of ply orientations, layup sequences, fiber volume fractions, temperature changes and distributions, foundation parameters and boundary conditions investigated.

Probabilistic analysis provides a tool for incorporating structural modeling uncertainties in the analysis of the structural response like frequency response. To the best of the authors’ knowledge, there is no literature covering the second order response statistics of nonlinear fundamental frequency of laminated composite plate resting on elastic foundations subjected to uniform and non-uniform change in temperature with temperature independent and dependent material properties based on micromechanical modeling with random system properties. This is the problem studied in the present Dissertation.

II. Methodology:

Fig: Basic Questions of Micromechanics

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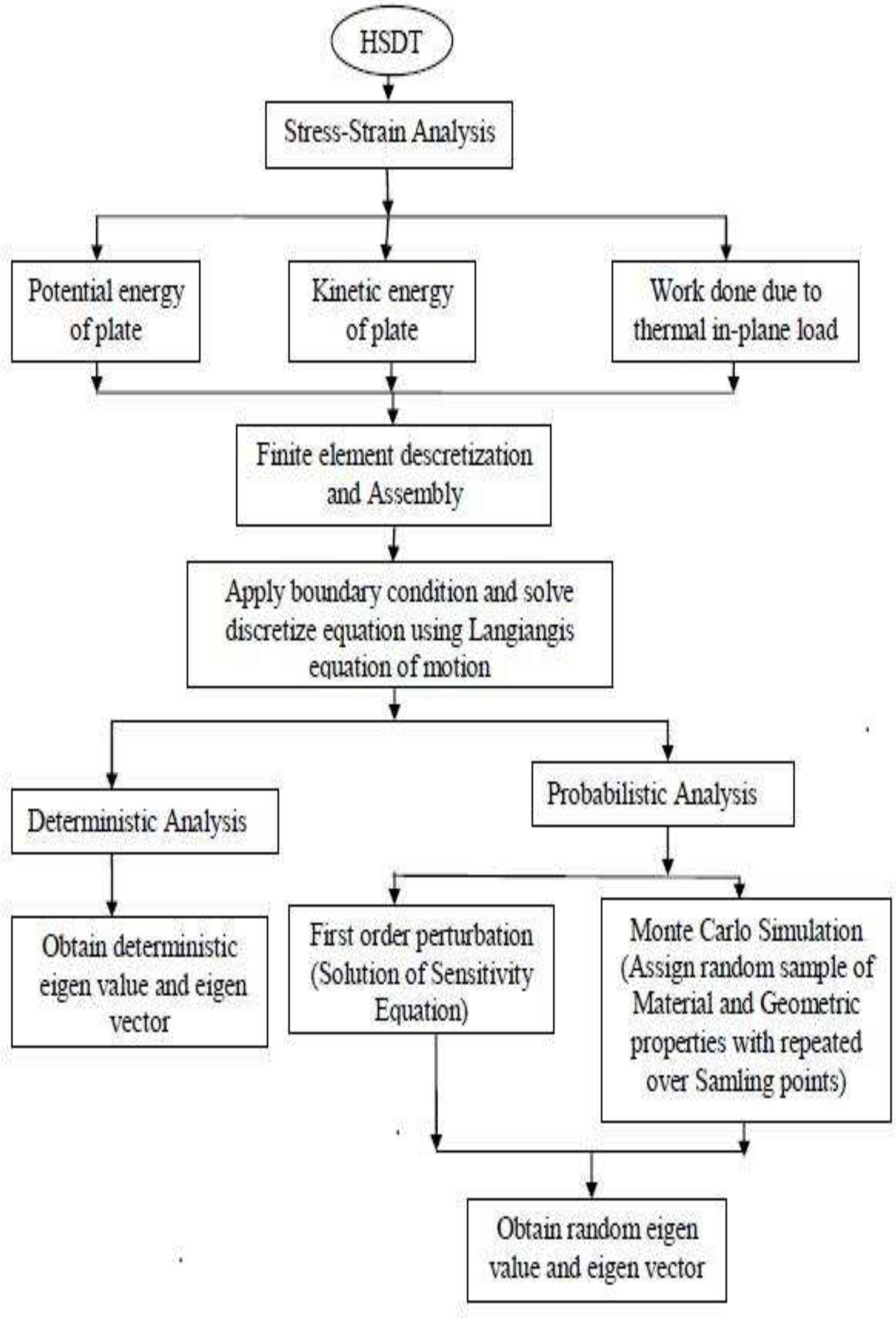
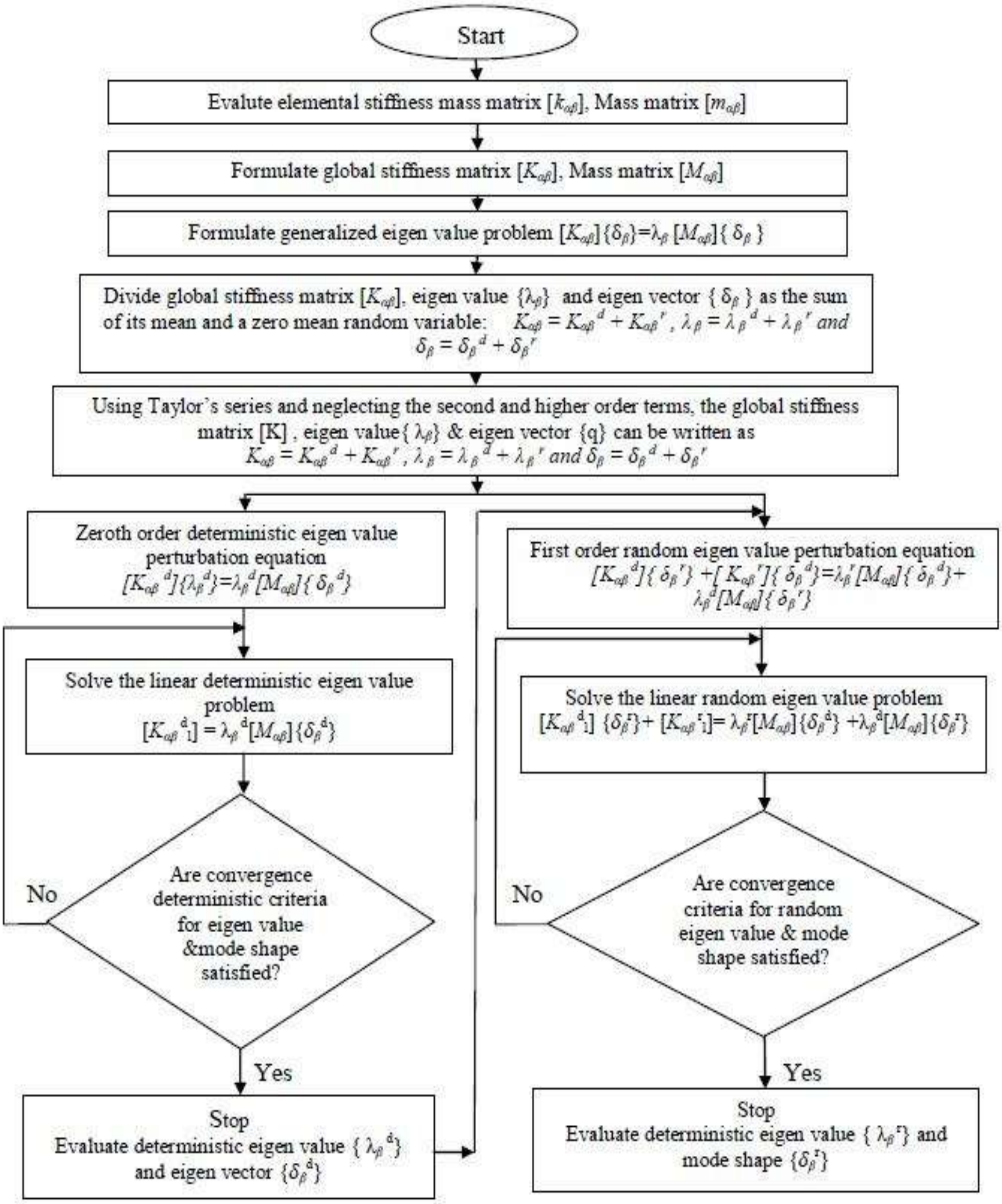


Fig-Overview of Present Study

Flow chart for the procedure of Stochastic Thermal Buckling Problem:-



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III. RESULTS:

The stochastic finite element analysis has been applied to obtain the mean and dispersion considering different random parameters of the thermal buckling load of laminated composite plate of graphite epoxy material. Fig.2**.**The lamina coefficients of thermal expansion including geometric and material properties are modelled as basic random variables RVs. The mean and standard deviation of the thermal buckling load are obtained considering the all random material input variables and thermal expansion coefficients as well as plate thickness taking separately as basic random variables (RVs) as stated earlier. However, the results are only presented taking SD/mean of the system property equal to 0.10 (Liu et al.1986), as the nature of the SD (Standard deviation) variation is linear and passing through the origin. Hence, the presented results would be sufficient to extrapolate the results for other COV value keeping in mind the limitation of FOPT (Klieber et al.1992). The thickness of all the lamina is assumed to be constant and of same material without varying individual property of materials used. The results obtained have been compared with MCS and those available in the literature. For the present study a nine nodded serendipity element, which results in 63 degree of freedom (DOFs) per element modified form HSDT based C^0 finite element model has been used for discretizing the laminate. Based on convergence, a (4x4) mesh has been used throughout for evaluation of the results. Results have been computed by employing the full (3x3) integration rule for bending stiffness matrices, thermal load vector and the geometric stiffness matrices and the reduced (2x2) integration rule for computing the shear stiffness matrices to avoid shear locking in the thin plates.

IV. DISCUSSIONS:

The stochastic finite element method [SFEM] has been applied to obtain the mean and coefficient of variations considering different random parameters of the thermal buckling load of laminated composite plate of graphite epoxy material. The lamina coefficients of thermal expansion including geometric and material properties are modeled as basic random variables (RVs). The thickness of all the lamina is assumed to be constant and of same material without varying individual property of materials used. The results obtained have been compared with MCS and those available in the literature. For the present study a nine nodded serendipity element, which results in 63 degree of freedom (DOFs) per element modified form HSDT based C^0 finite element model has been used for discretizing the laminate. Based on convergence, a (4x4) mesh has been used throughout for evaluation of the results. Results have been computed by employing the full (3x3) integration rule for bending stiffness matrices, thermal load vector and the geometric stiffness matrices and the reduced (2x2) integration rule for computing the shear stiffness matrices to avoid shear locking in the thin plates.

V. Conclusions:

The stochastic SFEM procedure outlined in the present study has been used to obtain the expected mean and coefficient of variation of the bucking load of the laminated composite plates subjected to uniform temperature rise with random system parameters. The followings are outcome of this limited study:

1. For various input random variables, environmental conditions for cross ply laminate, the increase in temperature effects significantly as the buckling load decreases. The effects are more prominent for temperature.
2. The combined effects of boundary conditions and random variables in thermal environment are studied; the plate is significantly affected by the thermal buckling load for clamp support conditions.
3. In general, the thermal effects are of due importance for analyzing the structure made of composite materials. The negligence of thermal effects in analyzing the system behavior may leave the design unsafe for manufacturing and may prone to failure for reliable operational requirements.
4. The CCCC plate at slightly higher temperature compared to other supports. The buckling is more dominant in plates of temperarture dependent material properties as compared to temperature independent case.
5. The thick plate are less affected by random input variables and other input variables compared to thin plates.

VI. Future scope:

There is a wide scope to extend the present study. Some of the possible extensions are:

- ➢ The present study can be extended for other geometries like cylindrical, spherical, and conical.
- ➢ The present study can be extended to various shapes of cut-outs.
- ➢ The study can be extended to include smart layers in the laminated composite plates.
- ➢ The study can be extended to functionally graded materials.
- ➢ In the present study we have used direct iterative method to handle geometric nonlinearity in the plate and elastic foundation. A more systematic approach may be used to handle the nonlinearity.
- ➢ Hygrothermal effects on laminated plate and shell.

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REFERENCES

[1] **H.S. Shen, F.W. Williams.** “Thermo-mechanical postbuckling analysis of imperfect laminated plates for softening nonlinear elastic foundations”, Composites structures, vol. 40. Pp. 55-66. 1998.

[2] **A. A. Khdeir. “**Thermal buckling of cross-ply laminated composite beams”, Acta Mechanics vol 149, pp. 201-213. 2001.
[3] **H.S. Shen. “**Postbuckling response and failure of symmetric laminates under uniform temperature rise”.
[4] **V. Sita Thankam, Gajbir singh, g. venkteswara Rao, A.K. Rath“**Thermal post-buckling behavior of laminated plates using a shear-flexible element based on coupled-displacement field”, Elsevior, composite structures vol. 59 pp. 351-359. 2003.
[5] **H. S. Shen. “**Thermal post-buckling behavior of imperfect shear deformable laminated plates with temperature-dependent properties”, Elsevior, Computational methods applied mech engg, 190. 5377-5390. 2001
[6] **Robert M. Jones. “**Thermal buckling of uniformly heated unidirectional and symmetric cross-ply laminated fiber-reinforced composite uni-axial in-plane restrained simply supported rectangular plates”, Elsevior, January 2005, sciencedirect, composite part A 36. 1355-1367. 2005
[7] **Ramesh Pandey, A.K. upadhyay, and K. K. Shukla, “**Hygrothermoelastic postbuckling response of laminated composite plate”, Journal of aerospace Engineering, January 2010/1
[8] **K. K Shukla and Y. Nath “**Analytical solution for buckling and post-buckling of angle-ply laminated plates under thermomechanical loading”, Pergamon, international journal of non-linear mechanics. Vol. 36. 1097-1108. 2010
[9] **H. S Shen and F. W. Willians “**Thermal postbuckling analysis of imperfect laminated plates on softening non-linear elastic foundations”Elsevior, composites science and technology vol-57, pp. 719-728 1997
[10] **H. S Shen “**Thermomechanical postbuckling analysis of imperfect laminated plates using a higher-order shear-deformation theory”, computers & structures vol. 66 pp. 395-409 1998.
[11] **M. Shariyat “**Thermal buckling analysis of rectangular composite plates with temperature-dependent properties based on a layerwise theory”, Elsevier, may 2007, sciencedirect.
[12] **Humayun R.H Kabir, “**Thermal buckling response of all-edge clamped rectangular plates with symmetric angle-ply lamination”, elsevior, composite structure**s** vol79. 148-155. 2007.
[13] **H. S Shen “**Hygrothermal effects on postbuckling of shear deformable laminated plates”, international Journal of mechanical sciences vol 43. 1259-1281 2001.
[14] **14. Achchhe lal, B. N. Singh, Rajesh Kumar, “**Effect of random system properties on thermal buckling analysis of laminated composite plates”. Elsevier, Comput struc(2009).
[15] Rajesh Kumar, **Dharamveer Singh** “Thermo-elastic static bending response of laminated composite plates with random system properties using stocastic finite element method” National Conference NCRDME-2010, October 29-30, 2010.
[16] **Rajesh Kumar, Dharamveer Singh** “stochastic finite element post buckling analysis of laminated composite plates under non-Uniform Parabolic Temperature Distribution” International Conference VETOMAC-VI at IIT Delhi, December 13-15, 2010.