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LARGE AMPLITUDE FREE VIBRATION ANALYSIS OF COMPOSITE PLATES BY FINITE ELEMENT METHOD

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ABSTRACT

The vast majority of the basic segments are for the most part subjected to dynamic loadings in their working life. All the time these parts may need to perform in extreme dynamic condition where in the most extreme harm comes about because of the resounding vibrations. Vulnerability to crack of materials because of vibration is resolved from stress and recurrence. Greatest abundance of the vibration must be in the restricted for the wellbeing of the structure. Henceforth vibration investigation has turned out to be essential in planning a structure to know ahead of time its reaction and to find a way to control the auxiliary vibrations and its amplitudes. The non-direct or substantial adequacy vibration of plates has gotten significant consideration as of late in light of the immense significance and intrigue connected to the structures of low flexural unbending nature. These effectively deformable structures vibrate everywhere amplitudes. The arrangement got in light of the heredity models give close to a first estimate to the real arrangements. The expanding interest for more sensible models to foresee the reactions of flexible bodies joined with the accessibility of super computational offices have empowered specialists to desert the direct speculations for non-straight strategies for arrangements. Incorporates the general presentation and the extent of present examination. The audit of writing limiting to the extent of the review has been exhibited in the Section. The general techniques for investigation of the overlaid composite plates have been quickly tended to in this part. The section 3 exhibits some data about the hypothetical foundation of limited component technique and composite materials. contains the scientific definition of the limited components. The versatile solidness and the mass lattices for the plate component have been detailed. The limit conditions have been executed by taking out the obliged degrees of flexibility from the worldwide firmness framework. quickly depicts the PC program execution of the hypothetical detailing introduced in Section 4. The diverse capacities and the related factors which have been utilized as a part of composing the codes in MATLAB have been introduced in a nutshell. A couple quantities of stream outline of the PC program has been represented. A few numerical cases which incorporate "substantial plentifulness free vibration analysis" have been introduced in the Section 6 to approve the plan of the propo sed strategy. wholes up and finishes up the present examination. A record of conceivable extent of augmentation to the present review has been attached to the closing comments. Some imperative distributions and books alluded amid the present examination have been recorded in the References area.

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1. INTRODUCTION

Fiber-strengthened composites, because of their high particular quality, and firmness . which can be customized relying upon the outline necessity, are quick supplanting the customary metallic structures in the weight delicate aviation and flying machine businesses. In fact, composite materials exhibit significant potential for wide use in airplane structures later on, particularly as a result of their focal points of enhanced durability, lessening in auxiliary weight, diminishment in weariness and consumption issues. The vast majority of the structures encounters serious dynamic condition amid their administration life; consequently the energized movements are probably going to have substantial amplitudes. The substantial plentifulness investigation of composite structures is significantly more intricate because of anisotropy, material couplings, and transverse shear adaptability impacts contrasted with their isotropic partners. The utilization of composite materials require complex explanatory strategies with a specific end goal to foresee precisely their reaction to outer stacking, particularly in serious conditions, which may actuate geometrically non-direct conduct. This requires proper plan criteria and exact estimation of the exhaustion life. Notwithstanding the typical challenges experienced by and large in the non-straight examination of structures, identified with the way that the hypothesis of superposition does not hold, presence and uniqueness of the arrangements are for the most part not ensured.

Finite element non-linear analysis

In the finite element formulation, we assume that the displacements of the finite element assemblage are infinitesimally small and the material is linearly elastic. In addition we also assume that the nature of the boundary conditions remain unchanged during the application of the loads on the finite element assemblage. With these assumptions, the finite element equilibrium equations derived were for static analysis = These equations correspond to a linear analysis of a structural problem because the displacement response U is a linear function of applied load vector R. Now applying a load of instead of R. The solution of non-linear problems by the finite element method is usually attempted by one of the 3 basic techniques: incremental or stepwise procedures, iterative or Newton methods and step-iterative or mixed procedures. In case of incremental procedures, load is subdivided into many small partial loads or increments usually equal in magnitude though generally they need not be equal. The load is applied one increment at a time, and during the application of each increment the equations are assumed to be linear. In other words a fixed value of stiffness matrix is assumed throughout each increment, but stiffness matrix may take different values during different load increments. The solution for each step of loading is obtained as an increment of the displacements. These displacement increments are accumulated to give the total displacement at any stage of loading and the incremental process is repeated until the total load is reached. The incremental method is analogous to the numerical method used for the integration of systems of linear or non-linear differential equations, such as the Euler method or Runge-Kutta method. The iterative procedure is a sequence of calculations in which the body or structure is fully loaded in each iteration. Because some approximate constant value of the stiffness matrix is used in each step,

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equilibrium is not necessarily satisfied. After each iteration, the portion of the total loading that is not balanced is calculated and used in the next step to compute an additional increment of displacements. The process is repeated until equilibrium is approximated to some acceptable degree. Some of the iterative methods are direct iteration technique and Newton-Raphson techniques. The mixed procedures utilize a combination of the incremental and iterative schemes. Here the load is applied incrementally, but after each increment successive iterations are performed.

2. LITERATURE REVIEW

2.1 Introduction

The analysis of plate and shell structures has a long history starting with membrane theory and then the bending theories. Plate and shell analyses are mainly based on 3 theories:

1. The classical plate theory (CPT)
2. The first-order shear deformation theory (FSDT)
3. The higher-order shear deformation theory (HSDT)

The effect of transverse shear deformation, which may be essential in some cases, is included in FSDT and HSDT, whereas it is neglected in CPT due to the Kirchhoff hypothesis. The classical laminate plate theory is based on the Kirchhoff hypothesis that straight lines normal to the under formed mid plane remain straight and normal to the deformed mid plane and do not undergo stretching in the thickness direction. These assumptions imply the vanishing of the transverse shear and transverse normal strains. The classical laminate theory has been used in the stress analysis of composite plates. However, it is only accurate for thin plates.

In FSDT, a first-order displacement field is assumed for transverse shear strain through the thickness. Appropriate shear correction factors are required in FSDT due to the assumption of constant transverse shear strain and shear stress through the plate thickness, which is contradictory to the zero shear stress condition on the bounding planes of the plate and actual stress states through the thickness. Higher-order polynomials are used to represent displacement components through the thickness of the plate in HSDT, and the actual transverse strain/stress through the thickness and the zero stress conditions on the top and bottom of a plate can be represented. A more accurate approximation of the transverse shear effect can thus be obtained with no shear correction factors. However, complexities in formulation and large computational effort make it economically unattractive. The free vibration of plates has been largely studied using the first order shear deformation theory (FSDT). The advent of digital computer along with its capability of exponentially increasing computing speed has made the analytically difficult problems amenable through the various numerical methods and thus making the literature rich in this area

2.2 Review on laminated composite plate

Ganapati et al. have studied nonlinear flexural vibrations of laminated orthotropic plate using C0 shear flexible QUAD-8 plate element. The nonlinear governing equations are solved using the direct iteration technique. Numerical results are obtained for isotropic, orthotropic and cross-ply laminated plates with simply-

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supported boundary conditions on immovable edges. It is observed that hardening behaviour is increased for thick plates and orthotropic plates. Bhimaraddi et al. have presented a critical analysis on nonlinear vibrations of heated anti symmetric angle-ply laminated plates using the parabolic shear deformation theory. Strains due to initial imperfections have also been retained using the von Karman type large deflection model. Numerical results are obtained by using the single mode approach to simply-supported plates, thus reducing five governing equations to a single nonlinear time differential equation involving quadratic and cubic nonlinearities. Srinivas has developed a sufficiently accurate refined analysis of composite laminates, which is much simpler than exact 3D analysis, for static and dynamic of composite laminates. He applied variational approach and considered transverse shear and inertia. Chandra shekhara et al. have investigated non-linear static and dynamic analysis heated laminated plates: a finite element approach by the use of a shear flexible finite element model. A wide variety of results are presented for the nonlinear response of rectangular and circular plates under thermal and thermo-mechanical loads. The influences of anisotropy, boundary conditions, aspect ratio, rotary inertia and stacking sequence on the thermally induced response are studied. View solved the vibration of thick symmetric laminates by Reissner/Mindlin plate theory and the p-ritz method with various combinations of boundary conditions. to incorporate the effects of transverse shear deformation and rotary inertia, first-order Reissner/Mindlin plate theory is employed. Finally results in terms of non-dimensional frequency parameters for various boundary conditions, aspect ratios and relative thickness ratios are presented. Large amplitude free flexural vibration analysis of composite stiffened plates have been carried out by Kant using a nine-noded Lagrangian element. The element is based on the first order shear deformation theory. The large deformation effect of the stiffened plated structures has been taken care by the dynamic version-linearo fequations von Kar obtained have been solved by the direct iteration technique using the linear mode shapes as the starting vectors. Singh et al. investigated the large amplitude vibratory behaviour of unsymmetrically laminated plates. For this purpose, an efficient and accurate four-node shear flexible rectangular material with six degrees of freedom per node. The element assumes bi-cubic polynomial distribution with sixteen generalized undetermined coefficients for the transverse displacement. The element stiffness and mass matrices are computed numerically by employing 3 × 3 Gauss-Legendre product rules. The element is found to be free of shear locking and does not exhibit any spurious modes. In order to compute the nonlinear frequencies, linear mode shape corresponding to the fundamental frequency is assumed as the spatial distribution and nonlinear finite element equations are reduced to a single nonlinear second-order Differential equation the geometrically non-linear free vibration of thin composite laminated plates is investigated by. **Harras et al.** [19] using a theoretical model based on Hamilton's principle and spectral analysis previously applied to obtain the non-linear mode shapes and resonance frequencies of thin straight structures, such as beams, plates and shells. The **Von Karman's-linear strain non displacement** relationships have been employed. In the formulation, the transverse displacement **w** of the plate mid-plane has been taken into account and the in-plane displacements **u** and **v** have been neglected in the non-linear strain energy

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expressions. A large amplitude vibration analysis of pre-stressed functionally graded material (FGM) laminated plates that are composed of a shear deformable functionally graded layer and two surface-mounted piezoelectric actuator layers has been carried out by **Yang et al.** Nonlinear governing equations of motion-order are d shear deformation plate theory to account for transverse shear strain and rotary inertia. A semi- analytical method that is based on one dimensional differential quadrature and Galerkin technique is proposed to predict the large amplitude vibration behaviour. **Singha et al**. have presented the large amplitude free flexural vibration behaviors of thin laminated composite skew plates are investigated using finite element approach. The formulation includes the effects of shear deformation, in-plane and rotary inertia. The geometric non-linearity based on **Von Karman's** assumptions is introduced. The non-linear governing Equations obtained employing Lagrange's equa iteration technique. The study reveals the redistribution of vibrating mode shape at certain Amplitude of vibration depending on geometric and lamination parameters of the plate Also, the degree of hardening behavior increases with the skew angle and its rate of change depends on the level of amplitude of vibration. **Amabili** has worked on theory and experiments for large-amplitude vibrations of rectangular plates with geometric imperfections. The von Karman nonlinear strain–displacement relationships are used to describe the geometric nonlinearity. A specific boundary condition, with restrained normal displacement at the plate edges and fully free in-plane displacements, not previously considered, has been introduced as a consequence that it is very close to the experimental boundary condition. The nonlinear equations of motion are studied by using a code based on pseudo-arc length continuation method. A thin rectangular stainless-steel plate has been inserted in a metal frame; this constraint is approximated with good accuracy by the newly introduced boundary condition. The plate inserted into the frame has been measured with a 3D laser system in order to reconstruct the actual geometry and identify geometric imperfections (out-of-planarity). The plate has been experimentally tested in laboratory for both the first and second vibration modes for several excitation magnitudes in order to characterize the nonlinearity of the plate with imperfections. Numerical results are able to follow experimental results with good accuracy for both vibration modes and for different excitation. Orthotropic plates with finite deformation a theory of plates with the effect of higher-order shear deformations, the governing equations for nonlinear vibration of orthotropic plate s with finite deformations are presented. The nonlinear free vibration is analyzed by the differential quadrature method. The differential quadrature approach suggested by Wang and Bert is extended to handle the multiple boundary conditions of the plate. The results show that the presented differential quadrature method is fairly reliable and valid. Influences of geometric and material parameters, transverse shear deformations and rotation inertia, as well as vibration amplitudes, on the nonlinear free vibration characteristics of orthotropic plates are studied. Sundararajan et al. have developed the non-linear formulation of free flexural vibrations of functionally graded rectangular and skew plates under Thermal environments, based on von Karman's a obtained using Lagrange's equations of motion results obtained here reveal that the temperature field and gradient index have significant effect on the nonlinear vibration of the functionally graded plate. The large amplitude, geometrically non-linear periodic vibrations of shear deformable composite laminated plates, a p-version, and hierarchical finite element is employed to define the model, taking into account the effects of the rotary inertia, transverse shear and geometrical non-linearity Ribeiro Harmonic forces are applied transversely to the plates and the steady-state periodic solutions are sought in the time domain by the shooting method. Fixing the amplitude of excitation and varying its frequency, response curves are derived. Several cases of modal coupling are found and the ensuing motions are analysed. The influences that the fibers orientations have on the forced vibrations are investigated. The efficiency and accuracy of the methods employed are discussed. Malekzadeh used a differential quadrature (DQ) method, to present large amplitude free vibration analysis of laminated composite skew thin plates. The governing equations are based on the thin plate theory (TPT) and the geomet in conjunction with von Karman assumptions. Some new results for laminated composite skew plates with different mixed boundary conditions are presented and are compared with those Obtained using the first order shear deformation theory based DQ (FSDT-DQ) method. Excellent agreements exist between the solutions of the two approaches but with much lower computational efforts of the present DQ methodology with respect to FSDT-DQ method. A nine-node isoperimetric plate-bending element has been used for the analysis of free undamped vibration of isotropic and fiber reinforced laminated composite plates **Pandit et al.** The effect of shear deformation has been incorporated in the formulation by considering the first-order shear deformation theory. An effective mass lumping scheme with rotary inertia has been recommended. Two types of mass lumping schemes have been formed. In one lumping scheme rotary inertia has also been introduced. Numerical examples of isotropic and composite rectangular plates having different fiber orientations angles, thickness ratios, and aspect ratio have been solved. The present results are very close to the analytical solutions. Few examples have been presented as new results. **Yongsheng et al.** have developed large Amplitude Flexural Vibration of the Orthotropic Composite Plate Embedded with Shape Memory Alloy Fibers. Based on the nonlinear theory of symmetrically laminated anisotropic plates, the governing equations of flexural vibration in terms of displacement and stress functions are derived. The numerical results show that the relationship between nonlinear natural frequency ratio and temperature for the nonlinear plate has similar characteristics compared with that of the linear one, and the effects of temperature on forced response behavior during phase transformation from Martensite to Austenite are significant. The effects of the volume fraction of the SMA fiber, aspect ratio and free vibration amplitude on the dynamical behavior of the plate are also discussed. **Allahverdizadeh et al.** Vibration amplitude and thermal effects on the nonlinear behavior of thin circular functionally graded plates, formulated in terms of von-Karman's dynamic equations, and a semi-analytical approach is developed. The plate thickness is constant and the material properties of the functionally graded plate are assumed to vary continuously through the thickness, according to a power-law distribution of the volume fraction of the constituents. For harmonic vibrations, by using assumed-time-mode method and Kantorovich time averaging technique, governing equations are solved.

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The nonlinear frequencies and associated stresses are determined at large amplitudes of vibration. Effects of material compositions and thermal loads on the vibration characteristics and stresses are examined. The numerical results obtained here are compared with available published results, based on various approaches. Houmat has proposed large amplitude free vibration of shear deformable laminated composite annular sector plates by a sector p-element. The effects of out-of-plane shear deformations, rotary inertia, and geometric non- linearity are taken into account. The shape functions are derived from the shifted Legendre orthogonal polynomials. The accuracy of the solution is improved simply by increasing the polynomial order. The time-dependent coefficients are described by a truncated Fourier series. The equations of free motion are obtained using the harmonic balance method and solved by the linearized updated mode method. The linear frequencies are found to converge rapidly down-wards as the polynomial order is increased.

3. THEORETICAL BACKGROUND

3.1 Basic concept:

In order to analyze an engineering system, a mathematical model is developed to describe the system. While developing the mathematical model, some assumptions are made for simplification. Finally, the governing mathematical expression is developed to describe the behavior of the system. The mathematical expression usually consists of differential equations and given conditions. These differential equations are usually very difficult to obtain solutions which explain the behavior of the given engineering system. With the advent of high performance computers, it has become possible to solve such differential equations. Various numerical solution techniques have been developed and applied to solve numerous engineering problems in order to find their approximate solutions. Especially, the finite element method has been one of the major numerical solution techniques. One of the major advantages of the finite element method is that a general purpose computer program can be developed easily to analyze the various kinds of problems.

The finite element method requires division of problem domain into many subdomains and each subdomain is called a finite element. Therefore, the problem domain consists of many finite element patches. The finite element method (FEM), or finite element analysis (FEA), it based on idea of building a complicated object with simple blocks or dividing a complicated object into small and manageable pieces. Application of this simple idea can be found everywhere in life, as well as in engineering.

The advent of the digital computer along with its exponentially increasing computational speed as well as core memory capacity has given the investigators a new direction to the analysis of the complicated structures thereby evolving simpler and more efficient methodologies. The widely used numerical methods to solve PDEs are the

- Finite element method (FEM)
- Finite volume methods (FVM)
- Finite difference methods (FDM)
- Exceptionally efficient higher-order version hp-FEM
- Generalized finite element method (GFEM)
- Extended finite element method (XFEM)

- Spectral finite element method (SFEM)
- Mesh-free finite element method

- Discontinuous Galerkin finite element method (DGFEM)

Among all the existing numerical methods, the finite element method is undoubtedly the most versatile and accurate one specially for structures having irregular geometry, material anisotropy, non-homogeneity and any type of loading and boundary conditions.

3.1.1 Why finite element method?
Design analysis: hand calculations,

- Experiments and computer simulations.
- FEM/FEA is the most widely
- Applied computer simulation method in engineering.

• Closely integrated with CAD/CAM applications.
3.1.2 Applications of FEM in engineering

Mechanical/Aerospace/Civil/Automobile Engineering

- Structure analysis (static/dynamics, linear/nonlinear)
- Thermal/fluid flows
- Electromagnetic
- Geo mechanics
- Biomechanics

3.1.3 Computer implementations
- Preprocessing (build FE model, loads and constraints)

- FEA solver (assemble and solve system of equations)

- Post processing (sort and display the results)

3.2 Composites
Generally speaking any material consisting of two or more components with different properties and distinct boundaries between the components can be referred to as a composite material. Moreover, the idea of combining several components to produce a material with properties that are not attainable with the individual components has been used by man for thousands of years. Correspondingly, the majority of natural materials that have emerged as a result of a prolonged evolution process can be treated as composite materials. Composite materials can be classified into two groups such as 'filled materials" and Reinforced. Fibers used in advanced composite are two types are natural fibers (i.e. carbon, boron, steel, glass, aramid, polyethylene fibers) and natural fibers (i.e. wood, coir, bamboo, wool, cotton, rice, natural silk, asbestos).Shows different types of fabrications in composites.
Transversely isotropic (there are three-planes of symmetry and, as such, it is orthotropic. In one of the planes of symmetry the material is treated as isotropic. An example of transversely isotropic material is a composite reinforced with continuous unidirectional fibers with all the fibers aligned in x1 direction. In this case the material in the plane perpendicular to fibers(x2- x3 plane) is treated as isotropic.
Isotropic (every plane is a plane of symmetry. For example a composite containing a large no. of randomly oriented fibers behaves in an isotropic manner**)**

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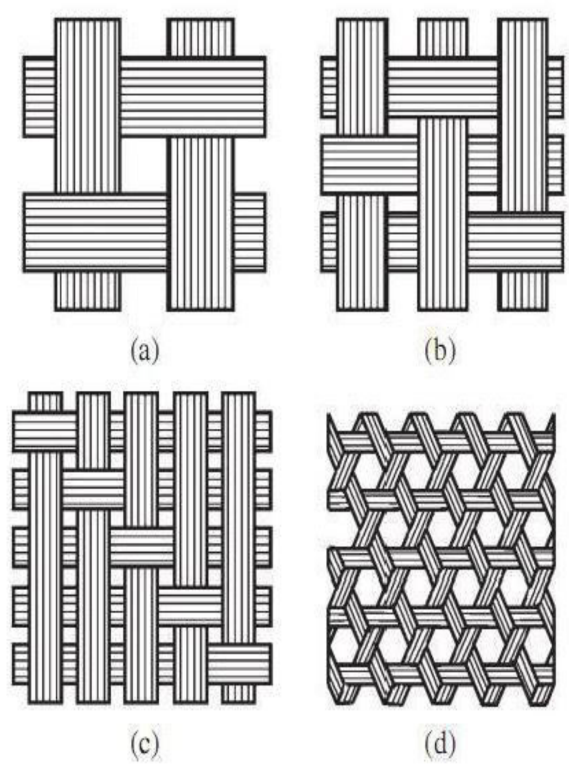

Plain (a), twill (b), and (c) biaxial woven, (d) triaxial woven fabrics.

4. FINITE ELEMENT FORMULATION

4.1 Introduction

In the finite element analysis, the continuum is divided into a finite number of elements having finite dimensions and reducing the continuum having infinite degrees of freedom to finite number of unknowns. The formulation presented here is based on assumed displacement pattern within the element and can be applied to linear, quadratic, cubic or any other higher order element by incorporating appropriate shape functions. In the following the element mass and stiffness matrices of the plate are derived. The element mass and stiffness matrices are then assembled to form the overall mass and stiffness matrices. Necessary boundary conditions are then incorporated. Reduced integration technique has been used to obtain the element mass and stiffness matrices. A **non-linear finite element model of an isoparametric plate** element is developed of the governing equations. A composite plate (**Mindlin's**) is chosen **plate** for the present analysis.

5. COMPUTER IMPLEMENTATION

5.1 Introduction

The finite element method has been established as a powerful numerical tool because of its broad spectrum of generality and its ease of applicability to rather more complex and difficult problems showing greater efficacy in its solution than that of any other existing similar techniques. This advantage of the method over others has led various research organizations and modern industries to endeavour the development of general purpose software packages and other in-house codes for solving practical problems of more complex nature. In an effort to make the method more powerful and to address more complicated problems, the finite element analysis programmes themselves become extremely complex and computationally involved. These programmes are available as black box modules which are to be used with the help of CAD programs. These conventional programmes cannot easily be modified to perform a desired task necessitating redesign and rebuild of finite element libraries requirement for finite element analysis programmes to be easily modifiable to introduce new analysis procedures, and new kinds of design of structural components or even emerging technology of new materials whenever needed. In the present investigation, the computer codes have been generated with such modularity which is amenable to easy modification whenever the need arises. Throughout all these years the finite element codes have been developed employing

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procedural language such as FORTRAN which is unstructured in its nature. Now there is a trend to pay attention to the verification, portability and reusability of the computer programmes during the process of their development and to the possibility of the use of other software products.

However, FORTRAN does not have the provision to meet all these requirements.

The **MATLAB** coding are efficient for the finite element problems. A computer programme based on the formulation given in the previous chapter is developed in **MATLAB** for large amplitude free vibration analysis of composite plates. There are 5 degrees of freedom per node. Composite plates of rectangular as well as square shape have been analyzed by this program.

5.2 Application Domain

The Computer Programmes have been developed in the present investigation by making use of the MATLAB code to include a wide spectrum of application domain. Computer programme codes have been written to incorporate various boundary conditions of the structures. They have the analytical modules to solve the following types of problems:

- Large amplitude free vibration analysis of isotropic plate.
- Large amplitude free vibration analysis of laminated composite plate.

5.3 Description of the Programme

The finite element procedure involves 3 basic steps in terms of the computation carried out which may be termed as:

1. Preprocessor
2. Processor
3. Post processor

5.3.1 Preprocessor

This module of the programme reads the necessary information about the geometry and boundary conditions of the plate, material properties, loading configuration and its magnitude, and its properties etc. Also in this module, all the **nodal coordinates** and the **nodal connectivity** are generated.

5.3.1.1 Automatic Mesh Generation

The mesh division for the structures analyzed is generated automatically. The algorithm for this purpose is provided by a function **rectangularmesh**. The plate structure is divided into a number of elements by assigning the number of divisions in each direction. This information is given as input to the problem under consideration. The elements are numbered automatically

5.3.2 Processor

This module of the programmes performs the following tasks:

1. Generation of the element matrices.
2. Assembly of the element matrices into global matrices.
3. Imposition of the boundary conditions.
4. Determination of eigenvalues and eigenvectors for the free vibration analysis using simultaneous vector iteration technique.

5.3.3 Postprocessor

In this part of the programme, all the input data are echoed to check for their accuracy. The function print-disk is used to print the output data in terms of non-linear frequency ratio, eigenvalue etc. The results are stored in a series of separate output files for each category of problems analyzed and those values are used to prepare tables and graphs etc. From 0.2 to 1.0. The results have been compared with different papers. It can be seen that the values of the references are on the lower side. This is because of the different

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techniques chosen by them for the solution of the non-linear equations. Their formulations have been based on appropriate linearization of the non-linear strain-displacement relations. They have also neglected the in-plane deformation terms. In the present investigation, in-plane deformation terms have been considered and no approximating procedure is used. Hence the present result may be deemed as more accurate.

6.2 FREE FLEXURAL VIBRATION OF LAMINATED COMPOSITE PLATE

In order to verify the accuracy of the results obtained in the free flexural vibration of laminated composite plate, a comparison has been done with published ones. Table 6.2 shows the comparison of linear natural frequencies with view.

6. RESULTS AND DISCUSSION

The finite element formulation of large amplitude free vibrations of isotropic and composite plates has been presented. The computer programming based on this method has been put forward in chapter-5.Examples have been worked out to validate the proposed approach. A number of examples have been presented and comparisons have been made with the results of earlier investigators wherever possible. The examples include square and rectangular plates with various boundary conditions. Eight - node plate element is considered with five degrees of freedom per node. from 0.2 to 1.0. The results have been compared with different papers. It can be seen that the values of the references are on the lower side. This is because of the different techniques chosen by them for the solution of the non-linear equations. Their formulations have been based on appropriate linearization of the non-linear strain-displacement relations. They have also neglected the in-plane deformation terms. In the present investigation, in- plane deformation terms have been considered and no approximating procedure is used. Hence the present result may be deemed as more accurate.

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7. CONCLUSIONS

The following conclusions may be made from the investigation of the large amplitude free vibration analysis of composite plate by finite element method:

1. For the materials having-linear higher to linear poi frequency ratios have been observed to be higher.
2. At lower values of amplitude to this significant effect on the non-linear to linear frequency ratio of vibration. But as the amplitude to thickness ratios increase there is remarkable increase in the non-linear to linear frequency ratios.
3. For the composite plate having higher breadth to thickness ratio, the non-linear to linear frequency ratio has been observed to be lower.
4. The non-linear to linear frequency ratio varies directly with respect to the plate aspect

ratios. The increase in the aspect ratio shifts the non-linear to linear frequency ratio towards the higher side.

5. Non-linear to linear frequency ratios are higher in cross-ply laminates as compared to angle-ply laminates of same geometric and material properties.

FUTURE SCOPE OF RESEARCH

Material nonlinearity may be taken into account in the formulation for further extension of the laminated composite plate configurations.

The present formulation can be extended to include the large amplitude free vibration of stiffened composite plates.

The plates studied here are of uniform thickness. The elements can be modified to incorporate the composite plates of varying thickness.

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