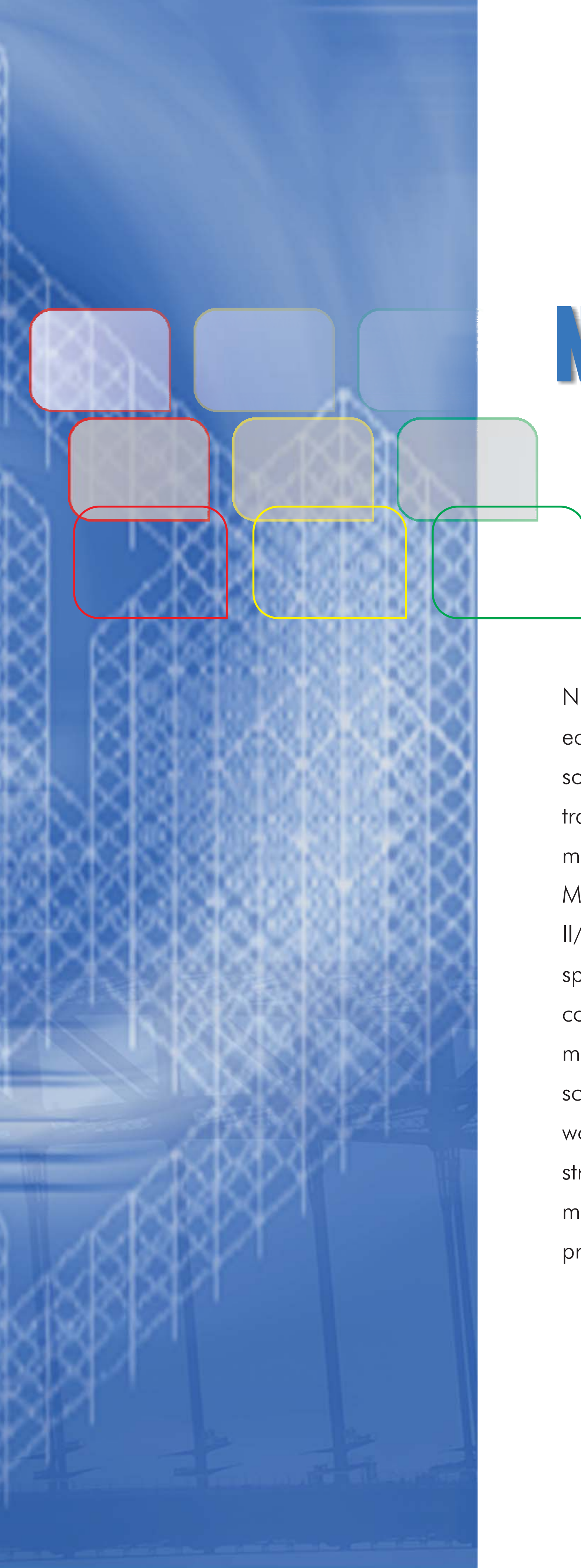
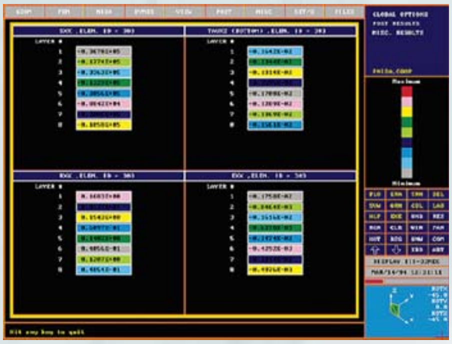
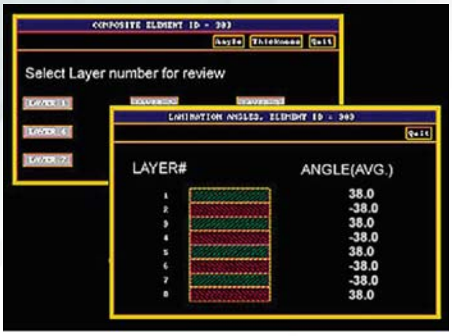


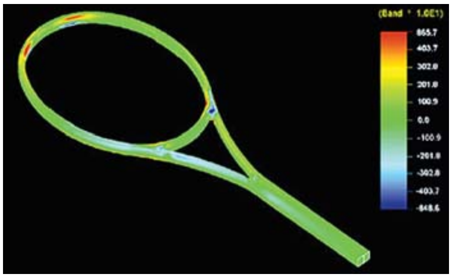
NISA - Composite

NISA II/COMPOSITES is the most powerful and economical general purpose finite element program to solve a wide range of static, dynamic, buckling, heat transfer, optimization and nonlinear (both geometric and material) analysis problems encountered in Aerospace, Mechanical and Civil Engineering environments. NISA II/COMPOSITES, which is a part of NISA II, is tailored specifically for accurate and efficient analysis of composite structures using state-of-the-art solution methods, convergence techniques and time integration schemes. NISA II/COMPOSITES is considered to be the world's best program for solving linear and nonlinear structures made of composite materials. The composites module is directly interfaced with DISPLAY III/IV for post-processing the results.

NISA - Composite







COMPOSITE ELEMENT LIBRARY

- 3D Layered Composite Shell
- 3D Layered Sandwich Shell
- 3D Solid
- Axisymmetric Layered Composite Solid

ANALYSIS FEATURES

- No restriction on the lamination
- Variable thickness and rotation angles
- Edge effects and delamination can be predicted
- Nodal temperatures and temperature gradients may be specified
- Temperature dependent material properties
- Interlaminar stresses satisfying 3D equilibrium equations

MODELING FEATURES

- Graphical representation of lamina thickness and angles across the laminate
- Draping of fabric over surfaces of general curvature

FAILURE THEORIES

- Maximum stress
- Modified Hill-Mises
- Tsai-Wu
- Delamination

OUTPUT

- Plots of original and/or deformed geometry
- Contour plots in any layer of displacement, stress components, and stress resultants
- Filtered stress output
  - The ratio of actual to allowable stress is computed. The output is suppressed if this ratio is below the user specified filtering stress ratio
- Stress survey plots
  - This special survey plot searches for the most critical stress ratio in all layers of each element. It prints an integer number, representing the most critical percentage of allowable stress on each element
- Largest magnitudes of the displacement vector
- Highest stress resultants in descending order of magnitude

NISA - Composite

NISA Composite

NISA II/COMPOSITES is an integrated part of the general purpose finite element program NISA II. The elements of NISA II/COMPOSITES can be used with all the elements of NISA - including isotropic (or orthotropic) shells, solids, beams, spars, mass, and spring elements and thus complete analysis capability is available for all composite and hybrid structures.

The **NISA/COMPOSITE** element library includes: These elements have no restriction on the number of layers, and each layer may have different thickness, orientation angle and material properties. The lamination may be symmetric or unsymmetric. For shell elements, transverse (interlaminar) shear deformation and `bending extensional' coupling are included.

THREE-DIMENSIONAL LAYERED COMPOSITE SHELL - The element is composed of several layers of orthotropic materials with varying thicknesses and material properties. The Tsai-Wu and Hill-Mises failure theories are available for these elements.

THREE-DIMENSIONAL SANDWICH SHELL - In sandwich composite elements, the face sheets are thin which resist extensional and inplane shear deformation and a thick corematerial which resists transverse shear. The face sheets themselves can be made of laminated composites and the core may be orthotropic. Multiple cores of more than two face sheets are allowed and the sandwich construction need not be symmetrical.

THREE-DIMENSIONAL COMPOSITE SOLID (OVERLAY) ELEMENT - In this element, solid is assumed to be composed of several lamina, each lamina may have different material properties and lamination angles. Each group of lamina is considered as a solid element. The normal stress and interlaminar shear stress are most accurately determined at any desired location. The element is capable of predicting displacement and stress variations, including edge effects accurately.

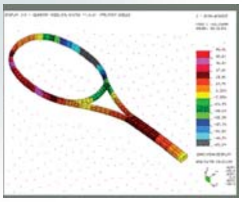
Highlights of the Element Library

- Consistent or lumped mass formulations for dynamic analysis
- Deformation dependent concentrated force and follower pressure for non-linear analysis.
- Material nonlinearity with elastoplastic material model
- Specified nodal temperatures with temperature gradients through thickness.

Input and modeling features for Composite structures

There is no restriction on the lamination. Any number of layers or materials may be laid up at any angle. In the most general case, each layer is a different material. Nodal temperatures and temperature gradients may be specified and material properties may be temperature dependent.

With the higher-order isoparametric formulation, large geometrical regions may be modeled with a single element, and curved boundaries may be fit with a piecewise quadratic or cubic curve.

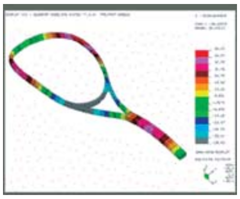


Tennis racket with optimized fiber orientation--first torsional mode

The shell elements are doubly curved but the surface is completely described by specifying only the three coordinates of each node. Thus, the input is as simple as for plate elements.

One of the special problems of composite analysis which arises in modeling curved structures is specifying the fiber orientations. Most programs give the user only one option - to measure the angles from a specified side of the element. If a detailed model is used, this requires the user to prepare a new set of angle data for each element.

NISA II/COMPOSITES has this option as well as six others, including the option of defining a rotation angle based on local coordinate system. These options simplify the analysis of singly or doubly curved structures by defining lines on the shell surface, which are projections of the global axes. Rotations are in every case about the shell normal and measured from these well defined reference lines. Fiber orientations can be defined at element or node level in either local or global system. Several local coordinate systems can be defined and referenced for defining the fiber orientations.



Tennis racket with optimized fiber orientation--combined bending torsional mode

The result of all this is that modeling a composite structure turns out to be no more difficult than modeling its metal counterpart. All these unique capabilities of NISA saves tremendous amount of time in modeling a composite structure

Buckling and Eigenvalue Analysis

Buckling analysis is used to extract natural frequencies and corresponding mode shapes of a structure when there is no dissipation of energy due to damping. Buckling analysis is used to find critical load factors at which a structure becomes elastically unstable. This analysis is properly termed `bifurcation buckling.'

NISA - Composite

(The post-buckling behavior of the structure can be analyzed using NISA II/Non-linear analysis.) Determination of these bifurcation points requires eigenvalue extraction. NISA II provides several different solution techniques to find the buckling load factors, natural frequencies and mode shapes of the structure. Very efficient and accurate techniques such as subspace iteration (conventional and accelerated), inverse iteration and Lanczos methods are available for the eigen extraction.

Modal Dynamic Analysis

NISA II/DYNAMICS is an independent module and can be used in conjunction with NISA II to solve a wide variety of problems encountered in dynamic analyses using Modal Superposition. The following analysis features are available:

- Transient Dynamic Analysis to evaluate the response of a given structure to an arbitrary loading.
- Shock Spectrum Analysis may be used to determine the response of a structure to an arbitrary oriented shock input
- Frequency Response Analysis can be used to compute the steady state response of a structure to harmonic loads defined by amplitude and phase spectra.
- Random Vibration Analysis can be used to obtain the statistical parameters of response quantities such as power spectral densities (PSD) and mean square values of structures subjected to a stationary random loading or ground excitation (such as earth uake, etc.).

Direct Transient Analysis

Direct Transient Analysis solves the coupled system of dynamic equilibrium equations. State-of-the-art numeric integration schemes and iteration methods are employed to achieve accurate and cost effective solutions for linear and nonlinear problems. Geometric and material nonlinearities can be considered. The features include:

- Implicit and explicit time integration schemes
- Consistent or lumped mass matrix
- Discrete damper elements and proportional (Rayleigh) damping Non-zero initial displacements and velocities, and moving boundary conditions
- Self-adaptive time steps for implicit and explicit scheme Geometric and material nonlinear behavior
- Moving frames of reference- centrifugal and Coriolis forces

Analysis Features

- NISA II/COMPOSITES is a general purpose finite element program which is tailored specifically for the accurate and efficient analysis of a wide range of composite structures. O
- Many levels of structural idealization are possible. An orthotropic material model is available for plane stress, plane strain,axisymmetric, general shell, and solid elements. The directions of orthotropy may be constant within each element, or may vary continuously form node to node.
- The heart of NISA II/COMPOSITES is a family of general laminated shell elements based on shear deformation theory and three dimensional solid elements based on elasticity theory. These elements are suited for the analysis of laminated structures with anisotropy as well as the special cases of orthotropy, transverse isotropy and isotropy.
- A single composite general shell element may be used to model an arbitrary number of layers at any given angle. The finite element discretization is just on the shell midsurface. This allows a drastic reduction in both modeling and computation time.
- A special modification of the isoparametric laminated shell element has proven to be applicable to a very general class of sandwich structures, and this analysis capability is included in NISA II/COMPOSITES as a separate family of elements.
- The element consists of thin face sheets that resist extensional and inplane shear deformation and a thick core material which resists transverse shear. The face sheets themselves can be made of laminated composites and the core may be orthotropic. Multiple cores and more than two face sheets are allowed and the construction need not be Symmetrical.
- The elements in NISA II/COMPOSITES account for the effects of transverse (interlaminar) shear deformation, material anisotropy, and all possible bending - extensional - twist - shear couplings. Thermal loads may be computed, and residual stresses due to curing may be found.
- Most plate and shell analysis are based on the classical Kirchoff theory, which assumes that lines of material points normal to the neutral surface before deformation remain normal to it after deformation. The theoretical basis of NISA II/COMPOSITES includes transverse shear effects, which are accounted for by allowing these normals to rotate relative to the deformed neutral surface.
- Consider that G/E the ratio of shearing to extensional stiffness, is fixed for an isotropic material at $1/(2 + 2v)$, or about 0.40 for most metals. By contrast, for a unidirectional lamina of high modulus graphite-epoxy, the value can be as low as 0.01. Thus, it is apparent that the same loading will induce significantly more transverse shear deformation in composite structures than in their metal counterparts. Indeed, it is not difficult to find composite problems where transverse shear is the dominant response mode of the structure.
- NISA II/COMPOSITES also includes the effects of rotary inertia, the counterpart of transverse shear deformation for dynamic problems. For steady state and transient dynamics, this has been shown to be an important response mode for composite structures.

NISA - Composite

- The 3D composite solid element is based on the three dimensional elasticity theory and so, conceptually, includes all the possible bending, extensional, twist and shear couplings in the element formulation. These elements are suitable for analysis of thick to moderately thick composite structures in which considerable shear deformation is present. The element can also predict the normal stress (s_{nn}) accurately which plane stress based elements neglect.

Nonlinear Analysis

The ever increasing use of laminated composite structures in the aerospace, automotive, chemical and sporting goods industries, demands better understanding of their material and structural behavior not only in the linear range but also in the nonlinear range. To meet the increased application of laminated composite structures in these industries, NISA II, known for its outstanding capabilities for modeling composite structures is now enhanced with nonlinear formulations. Currently, the four and eight noded degenerated composite shell elements have nonlinear capability whereas for the solid element development is in process.

Analysis highlights for nonlinear composites:

Geometrical nonlinearity with total and updated Lagrangian formulation which includes large displacements and large rotations.

Material nonlinearity with elastoplastic material model and the following yield criteria:

- Hill's anisotropic yield criterion with yield parameters that are updated during deformation history.
- Modified Hill's anisotropic yield criterion (C.F. Shih and D. Lee) which takes into account the differential strength in tension and compression and Bauschinger effect.
- Program accepts individual effective stress-strain curves in the principal material directions. Bilinear, piecewise linear or Ramberg-Osgood options are available for curved definitions.

Nonlinear Solution Procedures

- Simple incremental
- Newton-Raphson and Modified Newton-Raphson Iteration
- BFGS, Aitken, and Modified Conjugate Gradient Techniques

OUTPUT - The linear analysis output and post-processing are also applicable to nonlinear analysis. In addition, both the effective plastic strain and the effective stress are output at Gauss as well as nodal points. History plots are also available through the post-processor.

Loading and Boundary Conditions

NISA II/Composites allows the user a large variety of loading conditions as shown below:

Point loads
Follower point loads (for non-linear analysis)
Specified non-zero displacements
Pressure loads
Follower pressure loads (for non-linear analysis)
Body forces (centrifugal and linear accelerations)
Thermal loads
Thermal gradient through thickness for shell and beam elements

Kinematic Constraints

Kinematic constraints are relations among the unknowns that must be satisfied during the solution. The following forms of kinematic constraints are available:

Specified displacements
Rigid Links (elements)
Multi-point-constraints
Coupled displacements

Failure Theories

NISA-composites includes the following failure theories:

- Maximumstress
- Modified Hill-Von Mises
- Tsai-Wu
- Delamination

For material nonlinearity, the following yield criteria are available:

- Hill's anisotropic yield criterion
- Modified Hill's anisotropic yield criterion

All theories are applied on a ply-by-ply basis, in the principal material coordinate system of each layer. Delamination failures are predicted on the basis of interlaminar stress exceeding a specified allowable value.

Optimization of Laminated Composites with STROPT

STROPT is a general purpose structural optimization program integrated with the finite element analysis package NISA II. STROPT accommodates static and dynamic analyses and has an extensive library of finite elements containing 3D composite and sandwich elements. Listed below are the capabilities and features for the optimization of laminated composites.

- Objective function is either volume, mass or weight
- Constraints may be based on Hill-Mises and Tsai-Wu failure theories. In addition, constraints on displacements, stresses, natural frequencies, buckling load factors and maximum amplitudes can also be imposed

NISA - Composite

- Design variables may be layer thicknesses and/or rotation angles. In addition, cross sectional dimensions can also be treated as design variables
- Controls on the status of design such as free, fixed or linked
- Sensitivity analysis methods such as direct differentiation, adjoint variable and hybrid
- Optimization algorithms such as Recursive Quadratic Programming (RQP), Generalized Reduced Gradient (GRG), and Optimum Cost Bounding (OCB)
- Multiple load cases and boundary conditions

Output and Post-processing

NISA II/Composites offers a number of output and post-processing options to meet individual needs. All output is interactive and can be printed, very conveniently, from stress and displacement output files. The user may, at his discretion, select only a few of the options and select additional output through a restart after the displacement solution.

Output

The following output can be selectively controlled using the print control options of NISA II

- Nodal displacements
- Reaction forces at nodes where displacements are specified
- Element strain energy, element internal forces - and rigid element forces
- Element centroidal strains in the orthotropic direction of each layer
- Element stresses in orthotropic direction at Gauss points and node
- points of each layer
- Element stress resultants in the direction of top layer at each Gauss point and node point
- Average stress resultants in the top layer direction at each node of the structure
- Largest magnitude of displacement vector
- Highest stresses and stress resultants in descending order of magnitude

Post-Processing

Extensive post-processing features of DISPLAY III can be utilized to contour and interpret the results of the analysis. Some of the outstanding and frequently used capabilities are:

- Layer stresses
- Stress resultants
- Displacements
- Original and deformed geometry
- Stress survey plots
- Mode shapes
- Multiple load case deformed plots

Filtering the Output

Interpreting the results of a composite structural analysis can be a cumbersome task for various reasons such as:

- The volume of stress output increased with the number of layers.
- Maximum stresses may not necessarily occur at the top, middle or bottom surface of the shell.
- Strength of a composite lamina is direction-dependent and stresses must be transformed into a material coordinate system, which is different for each layer, before their significance can be measured.
- To overcome the above difficulties, filtering of output is very essential in composite structural analysis.

Filtering Stress Output

NISA II/ COMPOSITES incorporates a number of unique output features. For each layer, stress components are automatically computed in the local material axes. The stress values, including transverse shea r components, and the ratios of actual to allowable stresses are computed at the midsurface of each layer. The user may choose to print all stresses and stress ratios or may specify a threshold stress ratio and suppress printout of all stresses less than that fraction of allowable.

In addition to filtering the stress output using the threshold stress ratio, the output can also be filtered using the NISA II print control options. These options may be used to control the bulk of printout for the output quantities such as displacements, reactions, stresses, strain, energy, etc.

Stress survey plot

A special survey plot is available which searches for the most critical stress ratio in all layers of each element. This plot prints an integer number, representing the most critical percentage of allowable stress and the layer numbers in each element. Guided by a stress survey plot, the analyst may then use the stress printout and contour plots of layer stresses or stress resultants to examine structural response in more detail.

NISA - Composite

Scope of Analysis

NISA II/Composites comprise of a diverse group of analysis types to solve problems that are linear or non-linear in nature. NISA II/Composites can be used to solve the following types of structural analysis problems:

- Static
- Eigenvalue
- Suckling
- Nonlinear
  - Geometric
  - material
- Dynamic
  - transient dynamics (modal superposition or direct integration)
  - random vibration
  - frequency response
  - shock spectrum
- Optimization
  - optimum thicknesses and/or optimum rotation angles
- Heat Transfer
  - s teady state
  - transient

About us

Cranes Software International Limited is a leading provider of Computer Aided Engineering (CAE) services to the Automotive, Aerospace, Energy & Power, Civil, Electronics and Sporting Goods industries. Over 70 dedicated scientists, technology architects and software engineers providing NISA based solutions have helped major engineering companies reduce analysis turnaround time, improve user productivity, and ensure faster return on investments. The Company has its presence in 33 countries across the world and has a user base of more than 350,000.

With a mission statement to provide its customers the best in scientific technology and to enable its customers to define new limits, Cranes is setting new standards in the scientific and engineering field. *For more information, please visit* ***www.nisasoftware.com*** ***Email: nisa@cranessoftware.com***

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