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ACCESS 3 - APPROXIMATION CONCEPTS CODE FOR
EFFICIENT STRUCTURAL SYNTHESIS - USER'S GUIDE

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Abstract

This report serves as a user's guide for the ACCESS-3 computer program. ACCESS-3 is a research oriented program which combines dual methods and a collection of approximation concepts to achieve excellent efficiency in structural synthesis. The finite element method is used for structural analysis and dual algorithms of mathematical programming are applied in the design optimization procedure.

The ACCESS-3 program retains all of the ACCESS-2 capabilities and the data preparation formats are fully compatible. The following new features have been added in the program:

- four distinct optimizer options:
  - interior point penalty function method (NEWSUMT)
  - second order primal projection method (PRIMAL2)
  - second order Newton-type dual method (DUAL2)
  - first order gradient projection-type dual method (DUAL1)
- pure discrete and mixed continuous-discrete design variable capability
- zero order approximation of the stress constraints.

ACCESS - 3

Approximation Concepts Code for Efficient Structural Synthesis

User's Guide

1. INTRODUCTION

The ACCESS computer programs have been developed to demonstrate the effectiveness of an automated structural synthesis capability formed by combining finite element analysis techniques and mathematical programming algorithms using approximation concepts. Structures with prescribed configuration and given material properties are optimized so that their structural weight is minimized by modifying the sizing of finite elements,i.e. cross-sectional areas or thicknesses.

The ACCESS-1 program (see Refs. 1 and 2) was designed to test the effectiveness of the coordinated use of approximation concepts on problems of relatively small scale, subject to simple static constraints. As reported in Ref. 1, efficiency, in terms of the number of finite element structural analyses needed to obtain near optimal designs, was improved significantly over previously reported capabilities having comparable generality. However, many practical design problems were beyond the capacity of ACCESS-1 and consideration of more complicated constraints than those treated in ACCESS-1 was desirable.

The ACCESS-2 computer program was developed in response to these needs and to build a body of experience that can be used to set effective guidelines for future developments of large scale industrial application problems (see Refs. 3 and 4). Through the use of dynamic array allocation techniques and data transfer by sequential data files, ACCESS-2 is capable of treating larger problem sizes than its predecessor ACCESS-1. A thermal load analysis capability was added, providing experience with problems involving load vectors which depend on design variables. Frequency constraints were also installed. In addition to the usual Taylor series expansion with respect to the reciprocals of linked design variables, additional options for representing natural frequency constraints as first or second order Taylor series expansion with respect to regular linked variables were implemented. Finally the element library was extended. A constant strain triangular element with arbitrary orthotropic material properties (CSTOR) was included to model laminated fiber composite material membrane structures. A thermal shear panel element (TSP) was introduced to take uniform soak temperature effects into account, with emphasis on midplane symmetric wings.

The ACCESS-3 program continues along these lines and provide a further improved structural synthesis capability by combining dual methods and approximation concepts (see Ref. 5). The detailed analytical development of the methods implemented by the ACCESS-3 computer program as well as numerical results representing a substantial body of computational experience will be found in Ref. 6.

Approximation concepts are used to convert the general structural synthesis problem into a sequence of explicit problems of separable algebraic form. The dual method formulation exploits the separable form of each approximate problem to construct a sequence of explicit dual functions. These dual functions are maximized subject to nonnegativity constraints on the dual variables, which are the Lagrangian multipliers associated with the linearized behavior constraints.

The main advantages of the dual methods lies in their high level of computational efficiency, which is due to the fact that the dimensionality of the dual problem is relatively low for many structural optimization problems of practical interest. Another important advantage of the dual formulation is its ability to accommodate discrete design variables, e.g. available cross-sectional areas of bars, available gage sizes of sheet metal, the numbers of plies in a laminated composite skin, etc... The ACCESS-3 program provides two dual optimization algorithm options: (a) DUAL2 (2nd order Newton type of algorithm), which is restricted to pure continuous design variable problems; and (b) DUAL1 (1st order gradient projection type of algorithm), which can solve pure discrete and mixed continuous-discrete design variable problems.

In addition, a 2nd order primal projection algorithm called PRIMAL2 has been introduced, which operates, like NEWSUMT, on each explicit approximate problem expressed in terms of the reciprocal design variables. Hence a collection of four distinct optimizer options are available in the ACCESS-3 computer program: NEWSUMT, PRIMAL2, DUAL2 and DUAL1.

Another new feature of ACCESS-3 is that the stress constraints can be replaced with zero order explicit approximations instead of first order ones. The zero order approximations are obtained using classical stress ratio formulas. They can be expressed as simple side constraints, which is especially beneficial when dual methods are employed. A selection criterion permits automatic subdivision of the stress constraints in two categories: those requiring first order approximation (full linear Taylor series) and those for which zero order approximation (side constraint) is accurate enough (see Ref. 7).

In summary, the main feature of ACCESS-3 lies in the joining together of approximation concepts and dual methods. This solution scheme can be interpreted as a generalized optimality criteria method. Another new capability is the zero order approximation of the stress constraints based on the conventional "Fully Stressed Design" optimality criterion. Therefore the ACCESS-3 program can be regarded as an advanced research tool where mathematical programming and optimality criteria approaches coalesce to provide an efficient and reliable structural weight minimization method.

2. THE ACCESS-3 COMPUTER PROGRAM

2.1 Program organization

The fundamental structure of the ACCESS-3 program is outlined in Fig. 1. Upon activation the preprocessor reads and prints out the input data in a readable format. The preprocessor then computes all the ancillary data that are independent of changes in the design variables and it stores the results in appropriate arrays as well as in temporary external files (see Table 1). When preprocessing is completed successfully, the design process control (DPC) block is activated and it initializes the design iteration process. At the outset the design given in the input data is transferred to the approximate problem generator (APG), and this design is analyzed by the finite element method. Constraint functions are evaluated using the response quantities obtained from the finite element analysis and then the initial set of critical and potentially critical constraints is identified and tagged. Explicit approximate expressions for these tagged constraints are computed using the Taylor series expansion with respect to appropriate intermediate design variables. Reciprocals of independent design variables are used as intermediate variables throughout the program, except for an optional use of the independent design variables themselves when expanding frequency constraints. In ACCESS-3, the objective function is the structural weight and it may be expressed exactly and explicitly in terms of the independent design variables or their reciprocals. Thus, the APG block can generate an approximate problem statement of the form:

Minimize $W(\vec{X})$

$$\vec{X} = (x_1, x_2, \ldots x_n)$$

Subject to

$$\tilde{H}_q(\vec{X}) \geqq 0 \qquad q = 1,2,\ldots Q$$

where $W(\vec{X})$ and all $\tilde{H}_q(\vec{X})$ are explicit analytic functions of $\vec{X}$. Note that the number of constraints Q for this approximate problem is much smaller than that of the original structural design problem, because only the tagged constraints are included and all other constraints are temporarily ignored during a particular design stage.

The data which define the approximate problem are sent back to DPC and subsequently given to the optimization algorithm block (OA). The primary function of OA is to carry out a numerical search process which will improve the design by operation on the current approximate problem statement. Since OA deals with problems that are stated in algebraically explicit form, it is not even aware that these problems are related to structural design. Therefore, any established algorithm for inequality constrained minimization of a function of many variables may be used. However the main feature of ACCESS-3 is that special purpose, highly efficient OA have been selected, which capitalize upon the special mathematical structure of the explicit problems generated by APG. Unlike its predecessor ACCESS-2, in which only one general purpose OA was implemented (NEWSUMT), the new ACCESS-3 program offers a collection of four available options (NEWSUMT, PRIMAL2, DUAL2 and DUAL1). The user can select an OA from this collection, taking into account the size of the problem, the nature of the constraints and the definition of the design variables (continuous or discrete). Section 3.8 gives a description of the available OA.

After carrying out a numerical search with the approximate problem, the optimization algorithm (OA) block proposes an improved design $\vec{X}'$ to DPC. This step completes one stage of the design iteration procedure.

In summary, one stage of iteration includes one finite element structural analysis, one constraint deletion process, one sensitivity evaluation for retained constraints, and one optimization of an approximate problem. Since the final design is subjected to a detailed finite element analysis, the total number of finite element analyses equal the number of iteration stages plus one, which will be typically around 10. The iterative design process is terminated when one of the specified convergence criteria is satisfied.

2.2 Program Implementation

The ACCESS-3 computer program may be executed as a stand alone program. It consists of approximately 15000 FORTRAN statements. Two operational versions of the program exist, one for IBM 360/370 systems and the other for CDC 6600/7600 systems. Since it contains no machine dependent statements, it can be made operational on various computers, provided enough main memory capacity and auxiliary data storage support are available.

Auxiliary storage files are required as shown in Table 1. Files 10, 11, 12, 13, 14 and 15 are required for all problems. File 16 is required only when type 4 elements (TSP) are used in the structural model. Files 18, 19, 20, 21 and 22 are required only when second order expansions of frequency constraints are specified. File 17 is required only when zero order approximation of stress constraints is specified.

The required size of blank common is very problem dependent: i.e. it depends on the structural analysis model (number of nodes, elements and load conditions), the number of independent design variables, and the constraint types included. For certain problems, it also depends on the initial design. Hence, it is rather difficult to give explicit formulas which estimate the size of blank common requirements. Table 2 gives actual blank common array size requirements for several example problems.

Overlay or segmentation of the program can be designed easily by referring to Fig. 2. The simple 3 level overlay is adequate to solve most of the meaningful problems. If an operating system allows more flexible overlay structure, it is possible to decrease the core requirement further.

However, the net gain acquired by the elaborate overlay may not be significant, since most of the core is used for data and not for instructions.

All routines are written in standard FORTRAN IV language and they have been tested on:

(a) the IBM 360/91 using the FORTRAN-H compiler at UCLA

(b) the CDC 6600 at the NASA Langley Research Center.

Implementation on other computers will be straightforward provided those computers have the required main memory capacity. Except for the blank common arrays, 330_{10}k and 95_{10}k bytes are required on IBM 360/91 without and with program overlay, respectively. On a CDC 6600, the corresponding basic memory requirement is 100_8k words with overlay.

2.3 Restrictions and Limitations

The amount of main memory storage required for solution of a particular problem depends upon many factors, including the number of nodes, the number of elements, the number of design variables, the element types used, the kinds of constraints imposed, and even the initial design employed, etc. For static problems, it is necessary to retain two system stiffness matrices and the load vectors in core. For dynamic problems, three system matrices must be retained in core. If a problem involves dynamic constraints and thermal shear panel elements, four system matrices must be in core simultaneously. Also a complete approximate problem statement (all retained constraint values and all the corresponding derivative components) must be in core for the OA block. It is difficult to estimate the array size required for a system stiffness matrix in advance. Only the nonzero skyline of an upper half matrix is stored, hence the memory requirement depends on the node numbering scheme. For medium size problems (300-600 DOF), the density of nonzero elements in the matrix is usually 20-50% and a first approximation can be made by estimating the density based on observation of the finite element model. The main memory storage required for the integer portion of the blank COMMON is usually less than 10,000 words, but the real variable portion is very dependent on the nature of the problem. For problems in which the number of constraints retained tends to be larger and in which there are many independent design variables (e.g. structures involving laminated fiber composite skins) the constraint derivative array size [i.e. (Number of Design Variables) x (Number of Constraints Retained)] may limit the problem size, since this large array must be in core in addition to the instructions and local variables. Furthermore, a large number of available discrete values may also limit the problem size, since a separate set of discrete values must be associated to each independent linked design variable, in view of the design variable normalization process used in ACCESS-3.

When first order approximations are used, frequency constraints can be imposed on any subset of frequencies within the lowest NFREQ frequencies. If second order approximations are employed, all frequencies in the lowest NFREQ frequencies must be bounded.

Capabilities for aeroelastic constraints are not available in this version, therefore NMODE must be zero and the flight condition specification flags must all be zero.

There are 4 available optimization algorithms in ACCESS-3. However only NEWSUMT is a general purpose optimizer, which can be used even when the explicit approximate constraints are not linear in the reciprocal design variables. As a consequence, the possible combinations of frequency constraint approximations and optimization algorithms are not all acceptable; Table 3 shows the available combinations that may be used.

It is also important to recognize that only the DUAL1 optimization algorithm is applicable to problems involving discrete design variables. For the case of pure continuous design variable problems, all four optimizers are applicable. The algorithm options available for various kinds of problems are summarized in Table 4.

3. INPUT DATA PREPARATION

It is assumed that the reader is familiar with elastic structural analysis via the finite element displacement method, as well as with associated structural modelling techniques and typical data preparation procedures. Sufficient information for preparing the input data card images is given in Section 4, therefore, the explanations given in this section are limited to topics which require somewhat detailed technical discussion in order to avoid possible misunderstandings.

3.1 System of Units

Input data of the ACCESS-3 computer program may be prepared in any system of units as long as they are consistent. For example, if it is decided that the units for length and force are to be centimeters and Newtons, respectively, then the corresponding units for pressure load or allowable stress must be N/cm^2. Note that the material constant specification calls for the specific weight of the material, not its mass density. To be consistent lumped nodal mass should be given using weight rather than mass units. Example problems given in Appendix B, as well as the corresponding computer input data, are presented using numerical values associated with the US units, simply because all the examples were originally presented in the literature using US units.

3.2 Node Numbering Scheme

The system stiffness and mass matrices are stored in a vector form within the skyline of the nonzero elements, i.e. there are no operations or no storage allocations with elements that remain zero during the solution. This scheme allows somewhat more flexible node numbering arrangement than the ordinary band equation solver. It is better, however, to follow the same guidelines in preparing data as for a banded matrix solution scheme; i.e., differences among node numbers associated with an element must be kept as small as possible for all elements.

3.3 Symmetric Wing Model

If the webs of a midplane symmetric wing are modelled with SSP elements, only the upper (or lower) half of the wing is modelled. Assuming that the X-Y reference plane is the plane of symmetry, the X and Y displacement components and loading components are then anti-symmetric. Displacements and loadings in the Z direction are identical for both sides of the X-Y plane. For example, if a cantilever beam such as that shown in Fig. 3(a) is to be modelled using two SSP elements, then the simplified model should be that shown in Fig. 3(b). Note that only half of the load P needs to be applied to the node 3, since the other half is implicitly applied to the conjugate node 3' (which does not exist explicitly in the model). The SSP elements are always perpendicular to the X-Y plane of symmetry.

The assumed displacement function for SSP elements cannot accommodate uniform thermal expansion of each SSP element. If specified midplane symmetric temperature changes are specified for a midplane symmetric structural model, in which the vertical webs are represented by SSP elements, ACCESS 3 branches and makes a separate calculation which adds in the midplane symmetric temperature change effects. This is accomplished by assembling equilibrium equations for the midplane symmetric structure with all of the SSP elements replaced by TSP elements while only considering midplane symmetric temperature change loading. These equilibrium equations are solved for displacements $\vec{u}_{th}$ due only to midplane symmetric temperature changes. These thermally induced midplane symmetric displacements are superimposed on the previously computed midplane antisymmetric displacement state due to mechanical loads only. Treating the symmetric and antisymmetric contributions separately reduces the number of displacement degrees of freedom that need to be considered in each of the two analyses and for thin wings it also tends to improve the accuracy of the analysis by avoiding the poor conditioning often associated with simultaneous treatment of bending and membrane response. The strain state is computed based on the total displacement, and the stress state is computed by transforming the strain state using the stress-strain relationships.

3.4 Design Variable Linking and Stress Constraint Regionalization

The general concept of design variable linking is discussed in Sec. 2.3.1 of Ref. 1. In the ACCESS-3 computer program, if the sizes of some group of finite elements of the same type are controlled by a single design variable, these elements are said to belong to the same design variable linking group. The sizes of elements in a design variable linking group are modified in proportion to the initial sizes given in the input data.

Design variable linking groups are also used to define "regions" for the regionalization of stress constraints. The general idea of regionalization is described in Sec. 2.4.1 of Ref. 1. Elements which belong to the same design variable linking group form a region and only one stress constraint per load condition (the most critical) is considered for each group in any stage of the iterative design procedure. Selection of the critical stress constraints within a region is not rigidly fixed, but dynamically updated at the beginning of each stage. If the location of the critical stress constraints shifts frequently within a region from stage to stage the iteration process may be unstable, although this type of instability was not observed in solving any of the problems given in Ref. 1. However, if the user desires to remove the regionalization of stress constraints, it is only necessary to specify IGLINK = -200.

3.5 Failure Criteria

The CSTOR element is implemented to model structures made with orthotropic materials including multi-layered fiber composite laminates. While strength failure criteria for isotropic metal alloy materials are imposed using the von Mises combined effective stress, strength failure criteria for CSTOR elements are selected from 3 available options.
They are:

A. Maximum strain criteria

$$\bar{\varepsilon}_L^c \le \varepsilon_L - \alpha_L \Delta T \le \bar{\varepsilon}_L^t$$

$$\bar{\varepsilon}_T^c \le \varepsilon_T - \alpha_T \Delta T \le \bar{\varepsilon}_T^t$$

$$|\gamma_{LT}| \le \bar{\gamma}_{LT}$$

B. Stress interaction formulas

$$\left(\frac{\sigma_L}{F_L}\right)^2 \le 1$$

$$\left(\frac{\sigma_T}{F_T}\right)^2 + \left(\frac{\tau_{LT}}{F_{LT}}\right)^2 \le 1$$

C. Tsai-Azzi Criterion

$$\left(\frac{\sigma_L}{F_L}\right)^2 - \frac{\sigma_L \sigma_T}{F_L F_T} + \left(\frac{\sigma_T}{F_T}\right)^2 + \left(\frac{\sigma_{LT}}{F_{LT}}\right)^2 \le 1$$

where

ε_L : longitudinal strain

ε_T : transverse strain

γ_{LT} : shear strain

σ_L : longitudinal stress

σ_T : transverse stress

τ_{LT} : shear stress

$\bar{\varepsilon}_L^c$: allowable longitudinal compressive strain

$\bar{\varepsilon}_L^t$: allowable longitudinal tensile strain

$\bar{\varepsilon}_T^c$: allowable transverse compressive strain

$\bar{\varepsilon}_T^t$: allowable transverse tensile strain

$\bar{\gamma}_{LT}$: allowable shear strain

$$F_L = \begin{cases} \bar{\sigma}_L^t \text{ if } \sigma_L \geq 0 & \text{: allowable longitudinal tensile stress} \\ \bar{\sigma}_L^c \text{ if } \sigma_L < 0 & \text{: allowable longitudinal compressive stress} \end{cases}$$

$$F_T = \begin{cases} \bar{\sigma}_T^t \text{ if } \sigma_T \geq 0 & \text{: allowable transverse tensile stress} \\ \bar{\sigma}_T^c \text{ if } \sigma_T < 0 & \text{: allowable transverse compressive stress} \end{cases}$$

F_{LT} : allowable shear stress

ν_{TL} : Poisson's ratio relating to contraction in the longitudinal direction due to extension in the in-plane transverse direction

ν_{LT} : Poisson's ratio relating to contraction in the in-plane transverse direction due to extension in the longitudinal direction

Among the three alternative strength criteria, the maximum strain criterion is the most conservative while the stress interaction formulas are usually the least conservative.

3.6 Computation of Constraints

All constraints, except the side constraints, are normalized so that potentially critical constraint functions in the feasible region assume values between 0.0 and 1.0. Constraint functions are defined as follows:

Displacement Constraints

$$(\delta^{(U)} - \delta)/\delta^{(U)} \geq 0$$

$$(\delta - \delta^{(L)})/\delta^{(L)} \geq 0$$

Slope (Relative Displacement) Constraints

Slope

$$\frac{s^{(U)} - (\delta_2 - \delta_1)/d_p}{s^{(U)}} \geq 0$$

Relative Displacement

$$\frac{r^{(U)} - (\delta_2 - \delta_1)}{r^{(U)}} \geq 0$$

where d_p is the projection of the distance between the two points on a plane normal to the displacement components δ_1 and δ_2.

Stress (Strain) Constraints

$$\frac{\sigma^{(U)} - \sigma}{\sigma^{(U)}} \geq 0$$

$$\frac{\sigma - \sigma^{(L)}}{\sigma^{(L)}} \geq 0$$

For interaction formulas and Tsai-Azzi failure criteria, see Section 3.5, B and C.

Frequency Constraints

$$\frac{\omega^{(U)^2} - \omega^2}{\omega^{(U)^2}} \geq 0$$

$$\frac{\omega^2 - \omega^{(L)^2}}{\omega^{(L)^2}} \geq 0$$

3.7 Zero Order Approximation of the Stress Constraints

It is well known that in a structural synthesis problem, the stress constraints can often be efficiently treated using the classical "Fully Stressed Design" (FSD) concept. In this approach a stress ratio formula is employed to transform the stress constraints into simple side constraints, which can be interpreted as zero order explicit approximations (see Ref. 6, page 39).

The zero order approximation of stress constraints leads to a significant reduction in the number of behavior constraints retained in each explicit approximate problem. This feature is particularly beneficial when dual methods are employed, because the dimensionality of the dual problem corresponds to the number of constraints represented by first order approximations. On the other hand, the FSD procedure does not always converge to the true optimum and is sometimes the source of instability or divergence of the optimization process. However, in practical structures, it is observed that many of the stress constraints can be approximated with sufficient accuracy by zero order explicit approximations using FSD, while others require a more accurate approximation, using first order Taylor series expansion with respect to the reciprocal design variables.

The ACCESS-3 program provides the capability of selecting automatically the stress constraints for which a zero order approximation by FSD is sufficiently accurate. For each retained potentially critical stress constraint, the following test is accomplished (see Ref. 6):

$$\left| \frac{\text{STR - LRDV x GRD}}{\text{STR}} \right| \leq \text{EPS}$$

STR denotes the reference value describing the stress state, i.e., the tensile or compressive stress in a TRUSS element, the Von Mises combined effective stress in a CSTIS element, the longitudinal, transverse or shear strain in a CSTOR element, etc.... (see Section 3.5). LRDV represents the linked reciprocal design variable describing the element in which the current STR is evaluated[†]. GRD stands for the first partial derivative of STR with respect to LRDV.

All the stress constraints for which the test above is satisfied will be replaced with zero order explicit approxima-

[†]Note that LRDV = 1 in view of the normalization process used in ACCESS-3.

tions using stress ratio formulas (side constraints) while the others continue to be transformed into first order explicit approximations using Taylor series expansion (full linear constraints). Of course this selection of zero/first order approximations for the stress constraints must be repeated at each design stage, exactly like the well known truncation procedure for selecting the potentially critical constraints.

The severity of the test depends on the value adopted for the tolerance EPS, which is provided by the user. If EPS is taken close to 1, a small number of stress constraints will be first order approximated. The smaller is the value of EPS, the larger will be the number of first order approximated stress constraints.

3.8 Optimization Algorithms

The ACCESS-3 program includes four distinct optimization algorithms (OA) that the user can select depending upon the nature of the constraints, the expected number of strictly critical first order approximated constraints, the number of design variables, and their continuous or discrete character.

NEWSUMT Optimizer

The NEWSUMT optimization algorithm is the same as in the ACCESS-2 program, where it was the only available option. This optimizer implements a sequence of unconstrained minimi-zations techniques using a modified Newton's method and a quadratic extended penalty function feature to facilitate the unconstrained minimizations. One virtue of this interior penalty function type of OA is that it can usually be controlled so as to provide an improved design that is also feasible with respect to all of the constraints at each stage in the design process. NEWSUMT is thus particularly interesting when the constraints of the primary problem are highly nonlinear in the reciprocal variables, in which case each approximate problem must be solved only partially to preserve the design feasibility.

Another advantage of the NEWSUMT optimizer lies in its generality. Unlike the other optimization algorithms available in ACCESS 3, NEWSUMT can indeed accommodate explicit constraints which are not linear in the reciprocal design variables. As a result, NEWSUMT must be employed when second order Taylor series expansions are generated to represent the frequency constraints.

From the point of view of the computational cost, however, the NEWSUMT optimizer is far less efficient than the other available options. It should be selected only in the special cases previously indicated.

PRIMAL2 Optimizer

PRIMAL2 is a second order projection algorithm for problems with separable objective function and linear constraints. It uses a weighted projection operator to generate a sequence of Newton's search directions that are constrained to reside in the subspace defined by the set of active constraint hyperplanes (see Ref. 6, page 80). Like NEWSUMT, the PRIMAL2 optimizer generates a sequence of improved feasible designs with respect to the explicit approximate problem. Hence PRIMAL2 can be adequately used for seeking a partial solution to each approximate problem, in such a way that the constraints of the primary problem remain almost satisfied. This is accomplished by prescribing an upper limit on the number of one-dimensional minimizations performed before updating the approximate problem statement. Of course, PRIMAL2 is also well suited to solve exactly each approximate problem, in which case it produces the same iteration history as the dual methods, with comparable efficiency.

PRIMAL2 is computationally more economical than NEWSUMT. However, in the current version of the ACCESS-3 program, the PRIMAL2 algorithm has not been tested extensively enough and it should be used with circumspection.

DUAL2 Optimizer

The dual method formulation, which exploits the separable form of the approximate problem, consists in maximizing the explicit dual function subject to nonnegativity constraints on the dual variables. The efficiency of this approach is due to the fact that the dimensionality of the dual space, which is primarily dependent on the number of critical behavior constraints, is relatively low for many structural optimization problems of practical interest. In contrast to the primal optimizers NEWSUMT and PRIMAL2, which usually seek a partial solution to each approximate problem, reducing the weight while remaining feasible, the dual methods efficiently find the "exact" minimum weight solution of each separable approximate problem (see ¶2.4.1, Ref. 6). Therefore, at the end of any stage, the design may not be strictly feasible, in which case scale up is needed to obtain a feasible design. It should be noted, however, that the design infeasibility, if any, is usually small and decreases stage by stage.

DUAL2 is a dual method which employs a second order Newton type of algorithm to find the maximum of the dual function when all the design variables are continuous. Since the DUAL2 optimizer has been found to be very efficient in practice, it is the recommended option for pure continuous varialbe problems.

DUAL1 Optimizer

DUAL1 is a dual method which employs a specially devised first order gradient projection type of algorithm to find the maximum of the dual function when the design variables are all discrete or mixed continuous-discrete. The DUAL algorithm incorporates special features for handling the dual function gradient discontinuities that arise from the primal discrete variables. These discontinuities occur on specific hyperplanes in the dual space. The DUAL algorithm determines usable search directions by projecting the dual function gradient on the intersection of the successively encountered first order discontinuity planes. When a maximum has been obtained, the algorithm is restarted releasing all of the previously accumulated discontinuity planes. The whole maximization process is terminated when two successive restarts yield the same dual point. When all the design variables are continuous, the DUAL1 algorithm reduces to a special form of the conjugate gradient method; however it is generally less efficient than the DUAL2 optimizer for pure continuous variable problems.

Control over Convergence

Strictly speaking each new design generated by the optimization algorithm is an improved design only with respect to the approximate problem statement. When this new design is analysed by means of the finite element method, it may turn out that some behavior constraints are violated. This situation may occur when the design changes in one stage exceed the applicable range of the approximate problem statement.

The NEWSUMT optimizer is capable of locating feasible designs starting from an infeasible design; however violation of constraints usually has a deleterious effect on the convergence characteristics. The PRIMAL2 optimizer contains a built-in scaling procedure which readily finds a feasible critical design starting from any design (n.b. this scaling process is only applicable to static constraint violations). It is worthwhile noticing that constraint violation can usually be controlled or eliminated by appropriate use of the maximum step size parameter STEPMX (move limit) and its dynamic modification feature via the parameters STEPMX-multiplier and STEPMX-lower limit (see Section 4; block of data XXIV). Furthermore, constraint violation is less likely to occur if the optimization algorithms are used to seek a design improvement that corresponds to only a partial solution of each approximate problem. When the NEWSUMT option is selected, this can be done by reducing the number of response surfaces and/or increasing the response factor cut ratio (see Ref. 8). When the PRIMAL2 optimizer is used, the same effect is obtained by reducing the maximum allowable number of one-dimensional minimizations.

On the other hand, the dual optimizers DUAL1 and DUAL2 generate a sequence of not necessarily feasible designs and their performance is not adversely affected when design infeasibility is encountered. However, if for some reason the user wants to control constraint violation, this can still be done through the STEPMX parameters.

3.9 Printout Control Parameters

There are two parameters used to control the line printer output quantity, namely IPRINT and JPRINT. The greater the integer numbers assigned to these parameters, the more detailed output will be printed. IPRINT controls printout from all programs except the optimizers. Brief summaries of the output items are given in Table 5. Standard output will be obtained from the optimizers (see Tables 6,7,8 and 9). The standard value is JPRINT = 0 for all optimizers.

4. INPUT DATA DESCRIPTION

All input data are read in with fixed format, hence column positions of the punched data are of critical importance. Especially note that all blank columns are regarded as zeroes for numerical inputs.

I. Job description and heading cards (I1, 79A1)

The first column is used as follows

0 or blank: ordinary heading cards, whose contents in columns 2-80 will be printed on the page of the output.

1 : indicates that this is the last heading card and input data cards follow.

2 : request for immediate normal termination of this job.

Any number of cards may be used to describe or to comment the job. Note that the last heading card must have "1" punched in the first column. Without this, all of the data may be regarded as heading cards.

II. Primary control cards

Card 1 (7I5)

IOPT : 1 = Input data check only

2 = Structural analysis only

3 = Structural analysis and constraint function evaluation

see section 3.8 $\left\{ \begin{array}{l} \text{4 = optimization by the NEWSUMT optimizer} \\ \text{5 = optimization by the PRIMAL2 optimizer} \\ \text{6 = optimization by the DUAL1 optimizer} \\ \text{7 = optimization by the DUAL2 optimizer} \end{array} \right.$

IPRINT : Printout control parameter except for output from each optimizer
Standard output: IPRINT=2 (see Table 5).

IGLINK : 0 = standard execution
-200 = removal of stress constraint regionalization
-300 = removal of stress constraint regionalization for fixed size elements only

IANALY(1) : 1 = Compute displacement
0 = Skip displacement calculation

IANALY(2) : 1 = Compute stress/strain for all elements
0 = Skip stress/strain calculation

IANALY(3) : 1 = Compute eigenanalysis
0 = Skip eigenanalysis

IANALY(4) : 0 always

Card 2 (12I5)

IN : Total number of nodes

IBN : Number of boundary nodes

INL : Number of load conditions

IMATIS : Number of isotropic materials

IMATOR : Number of orthotropic materials

INITVG : Number of initial value groups for design variables

ILOWBG : Number of minimum size groups for design variables

IUPPBG : Number of maximum size groups for design variables

ITHLDG : Number of thermal load groups

IPRLDG : Number of pressure load groups

IDISVG : Number of discrete value groups for design variables

NVAL : Maximum number of available discrete values in each IDISVG discrete value group
Default option: if NVAL=0, the program adopts NVAL=20

Card 3 (10I5)

IETP(i), i = 1,2,...10

Number of elements in the i-th element type

i = 1 TRUSS

2 CSTIS (CST isotropic)

3 CSTOR (CST orthotropic)

4 SSP (symmetric shear panel)

5 PSP (pure shear panel)

6 TSP (thermal shear panel)

III. Node Coordinates (I5, 5X, 3E10.4)

IN cards are required to specify the node coordinates of node numbers 1 through IN. The order of the cards may be random.

n_i : Number of the i-th node

X_{ni} : X coordinate of the node n_i

Y_{ni} : Y coordinate of the node n_i

Z_{ni} : Z coordinate of the node n_i

IV. Boundary Conditions (4I5)

If all 3 degrees of freedom associated with a node are free, the node is not a boundary node. Otherwise it is a boundary node and for each boundary node, a card is required.

bn_i : i-th boundary node number

$$\left.\begin{array}{ll} IBX_{bn_i} & : \\ IBY_{bn_i} & : \\ IBZ_{bn_i} & : \end{array}\right\} \text{constraint code: } \begin{array}{l} 0 = \text{free} \\ 1 = \text{fixed} \end{array}$$

V. Element Data

If IETP(i) = 0 for the i-th element type, no data is required. For éach element type with IEPT(i)≠ 0, IETP(i)+1 cards are required.

Card 1 : element type number (I5)

Card 2-IETP(i)+1 : element information (12I5)

M_i	:	element number
NP	:	node number corresponding to the internal node number P
NQ	:	node number Q
NR	:	node number R
NS	:	node number S
LGN	:	linking group number, = 0 for the fixed size elements
IGN	:	initial value group number
LBGN	:	lower bound group number
UBGN	:	upper bound group number
MTLGN	:	material group number > 0 for isotropic materials: 1,2,... < 0 for orthotropic materials: -1,-2,...
SCC	:	side constraint code -1 : element size restricted by the lower bound only 0 : non-negativity constraint only 1 : element size restricted by the upper bound only 2 : element size restricted by both lower and upper bounds
DVGN	:	discrete value group number, = 0 for the continuous design variables. DVGN≠0 is valid only with DUAL1 optimizer (IOPT=6). Special option: if DVGN = 999, the program

adopts the following set of available discrete values for element M_i:

DMIN, 2xDMIN, 3xDMIN,...,NVAL xDMIN

where DMIN denotes the minimum gauge for element M_i (depending upon the LBGN value defined on the same data card). The special option DVGN=999 is useful for fiber composite material problems, where DMIN represents the smallest change in lamina thickness. For example, if the laminates are required to be symmetric, DMIN will be equal to the thickness of two plies.

Comments

1. Elements must be numbered starting from 1 through IETP(i) for each element type. For example, if a structure is modeled using 100 TRUSS elements and 300 CST elements, TRUSS element numbers are 1,2,3...100 and CST element numbers are 1,2,3,...300. Within an element type, order of element data cards may be random.
2. NR and/or NS are not required for element types with only 2 or 3 nodes per element.
3. LGN, linked group number, starts from 1 for each element type. For example, if a structure is modeled with 100 TRUSS and 300 CST elements, with 10 and 30 design variables allocated to TRUSS and

CST, respectively, then the linked group number for TRUSS runs from 1 through 10 and that for CST ranges from 1 through 30.

VI. Initial Values (7E10.4)

INITVG real numbers must be given. If INITVG > 7, two or more cards are required. The first value of the first card indicates the initial value for the group number 1, and so on.

VII. Lower Bound Values (7E10.4)

Minimum gauge values. ILOWBG real numbers must be given. If ILOWBG > 7, two or more cards are required. If ILOWBG = 0, no card is required.

VIII. Upper Bound Values (7E10.4)

Maximum gauge values. IUPPBG real numbers must be given. If IUPPBG > 7, two or more cards are required. If IUPPBG = 0, no card is required.

IX. Available Discrete Values (7E10.4/7E10.4...)

IDISVGxNVAL real numbers must be given, i.e.: for each of the IDISVG discrete value groups, NVAL discrete values must be specified in ascending order. If, for a given group, the number of available discrete values, say NVALG, is less than NVAL, the remaining (NVAL-NVALG) positions must be left as blank.

If IDISVGxNVAL > 7, two or more cards are required. If IDISVG = 0, no card is required.

X. Isotropic Material Data (6E10.4)

IMATIS cards are required and on each card the following 6 real numbers must be given:

E : Elastic modulus

ν : Poisson's ratio

γ : Specific weight

α : Thermal expansion coefficient

σ_{LB} : Allowable compressive stress

σ_{UB} : Allowable tensile stress

XI. Orthotropic Material Data (7E10.4/7E10.4/6E10.4)

IMATOR x 3 cards are required, i.e. for each material group, 3 cards are required, containing the following data.

Card 1

E_L : Longitudinal elastic modulus

E_T : Transverse elastic modulus

G_{LT} : Shear modulus

ν_{LT} : Longitudinal Poisson's ratio

γ : Specific weight

α_L : Longitudinal thermal expansion coefficient

α_T : Transverse thermal expansion coefficient

Card 2

ℓ_L :
m_L :
n_L :
Direction cosines of the longitudinal axis with respect to system reference coordinates

$\bar{\varepsilon}_L^t$: Tensile allowable longitudinal strain

$\bar{\varepsilon}_L^c$: Compressive allowable longitudinal strain

$\bar{\varepsilon}_T^t$: Tensile allowable transverse strain

$\bar{\varepsilon}_T^c$: Compressive allowable transverse strain

Card 3

$\bar{\gamma}_{LT}$: Allowable shear strain

$\bar{\sigma}_L^t$: Tensile allowable longitudinal stress

$\bar{\sigma}_L^c$: Compressive allowable longitudinal stress

$\bar{\sigma}_T^t$: Tensile allowable transverse stress

$\bar{\sigma}_T^c$: Compressive allowable transverse stress

F_{LT} : Shear allowable stress

Comments

1. The transverse Poisson's ratio ν_{TL} is internally computed using the relation $\nu_{TL}E_L = \nu_{LT}E_T$
2. Depending upon the failure criteria applied to the specific material, either strain allowables or stress allowables are left unspecified. Failure criteria options will be specified later in the category XXI.

XII. Lumped Nodal Loads

Two card groups are required to specify lumped nodal loads applied to the structure.

Card Group 1 (14I5)

Number of nodes subject to lumped nodal loads for each load conditions. INL integer numbers must be given.

Card Group 2 (I5, 5X, 3E10.4)

For each load condition, the specified number (by the group 1 cards) of cards must be given to identify the node numbers and associated load components in the reference coordinate system.

Supply one blank card if there is no lumped nodal load.

XIII. Pressure Load Data

No card is required if IPRLDG = 0. If IPRLDG > 0, the following 5 groups of cards must be given.

Card Group 1 (10I5)

Number of elements subject to pressure load for each element type. (Presently, only CSTIS and CSTOR elements can be subject to pressure loads).

Card Group 2 (14I5)

Pressure load ON-OFF for each load condition.

$ONOFF^k$ = 0 No pressure load for load condition k

= 1 Pressure load should be considered for the k-th load condition.

Card Group 3 (14I5)

Element numbers subject to pressure loads for all member types mentioned in card group 1. For each element type, the first element number subject to pressure load must be punched in columns 1-5; namely the group 3 cards should be subgrouped for different element types.

Card Group 4 (14I5)

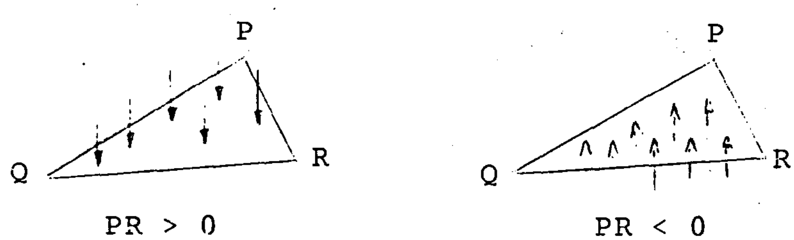
For each load condition corresponding to a load condition with $ONOFF^k$ = 1, an identical amount of data similar to that specified in the card group 3 must be given. Those numbers designate the pressure magnitude group numbers, which are the pointers to the pressure magnitude applied to the corresponding element type and element number. This set of cards should be given for all load conditions with $ONOFF^k = 1$.

Card Group 5 (7E10.4)

Pressure load magnitude for each pressure load group must be given. IPRLDG real numbers are required.

Comments:

1. The direction of the pressure force is determined by the node numbering scheme of the triangular element and also by the sign of the pressure load magnitude specified in the card group 5. When the P, Q and R nodes of the triangle are in counter clockwise order and the corresponding pressure magnitude has a positive sign, positive pressure is applied to the surface of the triangular region.



Pressure Load Sign Convention

2. Pressure applied on a single triangular surface must be uniform; no variation of pressure over an element surface can be represented.

XIV. Inertia Load Data

Self-weight in a gravitational field or uniform translational acceleration will be accounted for by specifying this set of data. Note that rotational inertia loads cannot be considered. Two groups of cards are required.

Card Group 1 (14I5)

$INERTL^k$: $k = 1,2,...INL$

Inertia load ON-OFF for each load condition.

1 : Inertia load exists

2 : No inertia load for the load condition

Card Group 2 (4E10.4)

For each load condition with $INERTL^k \neq 0$, one card will be required.

ACC^k : Magnitude of acceleration in units of the standard earth gravitational field (e.g. 4g)

X :
Y :
Z : Direction cosine components of the acceleration vector in the reference coordinate system.

Supply one blank card if there is no inertia load.

XV. Thermal Load Data

No card is required if ITHLDG = 0. If ITHLDG > 0, the following 5 groups of cards must be given.

Card Group 1 (10I5)

Number of elements subject to thermal load for each element type.

Card Group 2 (14I5)

Thermal load ON-OFF for each load condition.

ON-OFF^k = 0 No thermal load for load condition k

1 Thermal load should be considered for the k-th load condition.

Card Group 3 (14I5)

Element numbers subject to thermal loads for all member types mentioned in card group 1. For each element type, the first element number subject to thermal load must be punched in columns 1-5; namely the group 3 cards should be subgrouped for different element types.

Card Group 4 (14I5)

For each load condition corresponding to the load condition with ON-OFF^k = 1, an identical amount of data similar to that specified in the card group 3 must be given. Those numbers designate the temperature magnitude applied to the corresponding element type and element number. This set of cards should be given for all load conditions with ONOFF^k = 1.

Card Group 5 (7E10.4)

Temperature change for each thermal load group must be given. ITHLDG real numbers are required.

Comments:

1. Each element is considered to have uniform temperature.
2. Temperature change should be computed with respect to an appropriate uniform reference temperature. Note that if all elements are made of the same material and assume the same temperature, then thermal stresses are not induced.

XVI. Flight Condition Data

This block of data will be reserved for future development of the ACCESS-3 program which may include aeroelastic constraints. Supply one blank card.

XVII. Lumped Nodal Mass Data

Card 1 (I5)

NMASS : Number of lumped nodal masses

Card 2 - (NMASS + 1) (I5, 5X, E10.4)

N_i : Node number to which the mass is attached

w_{N_i} : Weight of the mass
Note that the magnitude w_{N_i} must be given in weight units, not in mass units.

Supply one blank card if there is no lumped nodal mass.

XVIII. <u>Stress Constraint Approximation Data</u> (3E10.4)

The automatic selection between zero and first order approximations for the stress constraints proceeds as follows. A retained potentially critical stress constraint will be replaced by its zero order approximation (using stress ratio), rather than by its first order Taylor series expansion (linearization), if the following test is satisfied:

$$\left| \frac{\text{STR-GRD}}{\text{STR}} \right| \leq \text{EPS} \qquad 0 \leq \text{EPS} \leq 1$$

where STR is the constrained quantity and GRD is the relevant gradient component (see Section 3.7). Two limiting cases are instructive:

if EPS = 0 : all retained stress constraints are replaced by full linear constraints (first order approximation).

if EPS = 1 : all retained stress constraints are replaced by simple side constraints (zero order approximation).

Initially the tolerance EPS is set to be EPS-initial and, at the end of each design stage, EPS is updated by

$$\text{EPS} = \text{EPS} \times (\text{EPS multiplier})$$

Since EPS-multiplier is chosen to be less than 1, EPS is decreased stage by stage, which means that more and more stress constraints are linearized as the design proceeds (but simultaneously more and more stress constraints are truncated; see card group XXI).

Three real numbers must be specified:

EPS-initial	:	initial tolerance for zero/first order approximation
EPS-min	:	lower limit of EPS
EPS-multiplier	:	EPS modification multiplier.

Supply one blank card if this capability is not used.

XIX-XXII Constraint Control Data

There are 4 types of constraints which can be specified. Each constraint type may have different truncation control, although the method used is identical for all types of behavior constraints. The truncation strategy is similar to the one used in ACCESS-1 (Refs. 1 and 2), but the sign convention defining the feasible region is reversed.

If a q^{th} constraint function at a design $\vec{\alpha}$ is evaluated as $h_q(\vec{\alpha})$ (see Section 3.6), $h_q(\vec{\alpha})$ is compared with a truncation boundary value (TBV) which is determined by:

$$TBV = + \{\underset{q}{\mathrm{Min}}[h_q(\vec{\alpha}) - C]\} x\ TRF + C$$

where $\underset{q}{\mathrm{Min}}$ is applied to all q's in the constraint type. Initially, TRF is set to be TRF-initial and at the end of each design stage, TRF is updated by

$$TRF = TRF \times (TRF\ multiplier)$$

Since TRF-multiplier is chosen to be greater than 1, TRF is increased stage by stage, i.e. TBV is decreased, which means that more and more constraints are truncated as the design proceeds (see Fig. 4).

It should be noted that the side constraints do not appear in this block of data, because there is no need to truncate them. The side constraint codes are specified in the element data.

XIX. Displacement Constraint Control Data

Card 1 (I5)

NDPC : Number of constrained displacement degrees of freedom

Card 2 (5E10.4)

TRF-initial	:	Initial truncation factor
TRF-max	:	Upper limit of TRF
C-cutoff	:	Cutoff base value
TRF-multiplier	:	TRF modification multiplier
Min. Norm Ftr.	:	Minimum constraint normalization factor. Constraints are usually normalized by the absolute values of the limiting values.

Card 3 - (NDPC+2) (3I5, 5X, 2E10.4)

$Node_i$	:	Node number associated with the i-th displacement constraint
Ixyz	:	Direction identifier 0 = not used 1 = X direction 2 = Y direction 3 = Z direction

Code : -1 = Lower bound only

0 = No constraint

1 = Upper bound only

2 = Both

Lower Bound : Lower bound of the displacement component

Upper Bound : Upper bound of the displacement component

XX. Slope/Relative Displacement Constraint Control Data

This constraint type is restricted to place bounds on relative displacement components of two arbitrary nodes. In other words, the difference between Y-displacement components of the L^{th} and U^{th} nodes may be bounded. But the difference between the Z-displacement of L^{th} and X-displacement component of U^{th} node cannot be bounded.

Card 1 (I5)

NSLC : Number of slope/relative-displacement constraints

Card 2 (5E10.4)

TRF-initial : Initial truncation factor

TRF-Max : Upper limit of TRF

C-cutoff : Cutoff base value

TRF-multiplier : TRF modification multiplier

Min. Norm. Ftr : Minimum constraint normalization factor

Card 3-(NSLC+2)   (3I5, E10.4)

$\text{Node}_i^{(L)}$: Node number of the L^{th} node associated with the i^{th} slope constraint

$\text{Node}_i^{(U)}$: Node number of the U^{th} node associated with the i^{th} slope constraint

I_{xyz} : Direction and code

0 : not used

$$\left.\begin{array}{l}1 : \text{X direction} \\ 2 : \text{Y direction} \\ 3 : \text{Z direction}\end{array}\right\} \text{relative displacement}$$

$$\left.\begin{array}{l}4 : \text{X direction} \\ 5 : \text{Y direction} \\ 6 : \text{Z direction}\end{array}\right\} \text{slope}$$

Upper Bound : Upper bound of the slope/ rel. displ.

Note:

1. If $I_{xyz} = 1$, for example, the constraint function is

$$1 - (U_x^{\text{Node}^{(U)}} - U_x^{\text{Node}^{(L)}})/\text{Upper Bound} \geq 0$$

2. If $I_{XYZ} = 4$, for example, constraint function is

$$1 - \frac{U_X^{\text{Node}^{(U)}} - U_X^{\text{Node}^{(L)}}}{D_{YZ}} /\text{Upper-bound} \geq 0$$

3. If lower bound is to be specified, node$^{(L)}$ and node $^{(U)}$ should be exchanged to transform it to an upper bound constraint.

XXI. Stress/Strain Constraint Data

Card 1 (10I5)

Code ^{MTYP} : Stress/Strain constraint code (see Section 3.5)

Except for element type 3

- -1 = read stress constraint code element by element
- 0 = no stress constraint
- 1 = all elements in this element type are constrained by lower bounds on compression stress
- 2 = all elements in this element type are constrained by upper bounds on tensile stress or Von Mises combined stress (Element Type 1 or Types 2,4,5,6)
- 3 = effectively this implies that both codes 1 and 2 are applied simultaneously

For element type 3

- -1 = read strain constraint code element by element
- 0 = no strain constraint imposed
- 1 = maximum strain envelope criteria imposed on all elements
- 2 = stress interaction criteria imposed on all elements
- 3 = Tsai-Azzi criteria imposed on all elements

Card 2 (7E10.4)

TRF-initial	:	Initial truncation factor
TRF-max	:	Upper limit of TRF
C-cutoff	:	Cutoff base value
TRF-multiplier	:	TRF modification multiplier
Min.Stress Norm. Ftr.	:	Minimum stress constraint normalization factor
Min.Strain Norm. Ftr.	:	Minimum strain constraint normalization factor
TEBCF	:	Truss Euler buckling control factor

If TEBCF > 0, TEBCF stands for the specified mean radius r of the truss element assuming tubular cross section. Stress constraint is

$$\sigma \geq \mathrm{Max}\{\sigma^{c}_{allowable}, \pi^2 E r^2/2\ell^2\}$$

If TEBCF < 0, it stands for the thickness (t) to mean radius (r) ratio of the truss element assuming cylindrical cross section. Stress constraint is

$$\sigma \geq \mathrm{Max}\{\sigma^{c}_{allowable}, \pi^2 EA/[4\ell^2 \cdot (\frac{t}{r})]\}$$

If TEBCF = 0, no Euler buckling constraints are considered.

Card 3 (14I5)

Stress/strain constraint specification for element type code, Code MTYP < 0. If all Code^{MTYP} are positive, no cards are required.

For each element type with Code MTYP = -1, stress/strain code must be given to all elements sequentially starting from element number 1.

Element stress/strain constraint code:

Stress code

-1 : only compression stress is bounded

0 : no constraint

+1 : only tensile (truss only) or Von Mises combined stress is bounded

+2 : both compressive and tensile stress are bounded.

Strain Code

same as $\text{Code}^{\text{MTYP}}$ specification

XXII. Natural Frequency Constraint Data

Card 1 (2I5)

NFREQ : number of lowest frequencies to be bounded

NSPACE : frequency constraint approximation scheme

0 = first order Taylor series expansion with respect to linked reciprocal variables (linear in the optimization design space).

1 = first order Taylor series expansion with respect to linked direct variables (with NEWSUMT optimizer only: IOPT=4)

2 = second order Taylor series expansion with respect to linked direct variables (with NEWSUMT optimizer only: IOPT=4)

Card 2 (7E10.6)

TRF-initial	:	Initial truncation factor
TRF-max	:	Upper limit of TRF
C-cutoff	:	Cutoff base value
TRF-multiplier	:	TRF modification multiplier
Min.Norm. Ftr.	:	Minimum constraint normalization factor
Eig. Conv.	:	Eigenvalue analysis convergence criteria (see note below)
Acc. Gravity	:	Acceleration of gravity If 0.0, American standard unit is assumed and replaced by 386.0 in/sec^2.

Note: Subspace iteration algorithm is used to obtain eigenvalues and eigenvectors. Iteration is judged to be converged if the relative differences of all eigenvalues are less than Eig. Conv.

Card 3 (I5, 2E10.4)

Code$^{f=1}$: constraint code

-1 = lower bound only

0 = not bounded

1 = upper bound only

2 = lower and upper bounds

Lower Bound : lower bound on the i^{th} eigenvalue (ω_i^2)

Upper Bound : upper bound on the i^{th} eigenvalue (ω_i^2)

XXIII. Flutter Constraint Data

Supply one blank card.

XXIV. Optimizer Control Parameters

Four distinct options are available for solution of the explicit approximate problem generated at each design stage (see Section 3.8). The following block of data takes on different meaning depending upon the value selected for IOPT (Card II).

If IOPT = 4 : NEWSUMT Optimizer Control Cards

Card 1: (5I5)

JPRINT : Optimizer printout control (see Table 6) standard output = 0

MAXSTG : Maximum allowable number of stages

MAXRSF : Maximum number of response surfaces per stage; i.e. response factor is reduced MAXRSF times before the approximate problem is updated

MAXODM : Maximum allowable number of one dimensional minimizations per response surface

JSIGNG : sign of feasible region

1 : feasible region is $g_q(\vec{\alpha}) \geq 0$

-1 : feasible region is $g_q(\vec{\alpha}) \leq 0$

Card 2: (8E10.4)

EPSSTG : Stage convergence criterion. Overall iteration is judged to be converged if both of the following conditions are satisfied at the end of the p^{th} stage.

$$|W_p - W_{p-1}|/W_p \le \text{EPSSTG}$$

$$|W_{p-1} - W_{p-2}|/W_{p-1} \le \text{EPSSTG}$$

EPSODM : Unconstrained minimization convergence criterion. Convergence is obtained if the relative values of total function at the ends of 3 successive one dimensional minimizations are not different by EPSODM.

RACUT : Response factor decrease ratio

RAMIN : Minimum response factor

STEPMX : Maximum step size at each stage (move limit). All design variable components are constrained by

$$\frac{1}{\text{STEPMX}} \le \beta_i \le \text{STEPMX} \qquad i = 1,\ldots B.$$

ITP : Initial transition point for the extended penalty function

Power Fr : specify = 0.5

Coefficient : specify = 1.0

<u>Card 3</u> (2E10.4)

STEPMX-mul : STEPMX modification multiplier

STEPMX-ℓ.ℓ. : Lower limit on the STEPMX

If IOPT = 5 : PRIMAL2 Optimizer Control Cards

Card 1 (3I5)

JPRINT	:	Optimizer printout control (see Table 7) Standard output = 0
MAXSTG	:	Maximum allowable number of stages
MAXODM	:	Maximum allowable number of one dimensional minimizations per stage; i.e. MAXODM search directions are computed before the approximate problem is updated. Special option: if MAXODM = 0, complete solution of the approximate problem is performed at each stage.

Card 2 (5E10.4)

EPSSTG	:	Stage convergence criterion. Same as NEWSUMT
DUMMY	:	not used
DUMMY	:	not used
DUMMY	:	not used
STEPMX	:	Maximum step size at each stage (move limit) Same as NEWSUMT

Card 3 (2E10.4)

STEPMX-mul	:	STEPMX modification multiplier
STEPMX-ℓ.ℓ.	:	Lower limit on the STEPMX

If IOPT = 6: DUAL1 Optimizer Control Cards

Card 1 (5I5)

JPRINT : Optimizer printout control (see Table 8). Standard output = 0.

MAXSTG : Maximum allowable number of stages

MAXRES : Maximum allowable number of restarts in the solution of the dual problem (discrete and mixed discrete-continuous cases).

MAXODM : Maximum allowable number of one dimensional maximizations per restart. MAXODM should be at least equal to the number of constraints retained in the first stage.

ICOMB : Specify = 1

Card 2 (5E10.4)

EPSSTG : Stage convergence criterion
Same as NEWSUMT

EPSODM : Dual maximization convergence criterion

TAUMAX : Maximum step size in dual space.
Standard option: if TAUMAX = 0, the program automatically estimates an appropriate value for TAUMAX and simultaneously determines a good starting point for dual maximization in the first stage. TAUMAX $\neq$ 0 can be used in order to reduce the storage requirement for computation of the intercept-distances to discontinuity planes

DUMMY : not used

STEPMX : Maximum step size at each stage (move limit in the primal space).

Card 3 (2E10.4)

STEPMX-mul : STEPMX modification multiplier

STEPMX-ℓ.ℓ. : Lower limit on the STEPMX

If IOPT = 7 : Dual 2 Optimizer Control Cards

Card 1 (2I5)

JPRINT : Optimizer printout control (see Table 9) Standard output = 0.

MAXSTG : Maximum allowable number of stages

Card 2 (5E10.4)

EPSSTG : Stage convergence criterion Same as NEWSUMT

EPSODM : Dual maximization convergence criterion. Convergence is achieved when the norm of the vector made up of the primal constraint values is less than EPSODM.

DUMMY : not used

DUMMY : not used

STEPMX : Maximum step size at each stage (move limit in the primal space).

Card 3 (2E10.4)

STEPMX-mul : STEPMX multiplier

STEPMX-ℓ.ℓ. : Lower limit on STEPMX.

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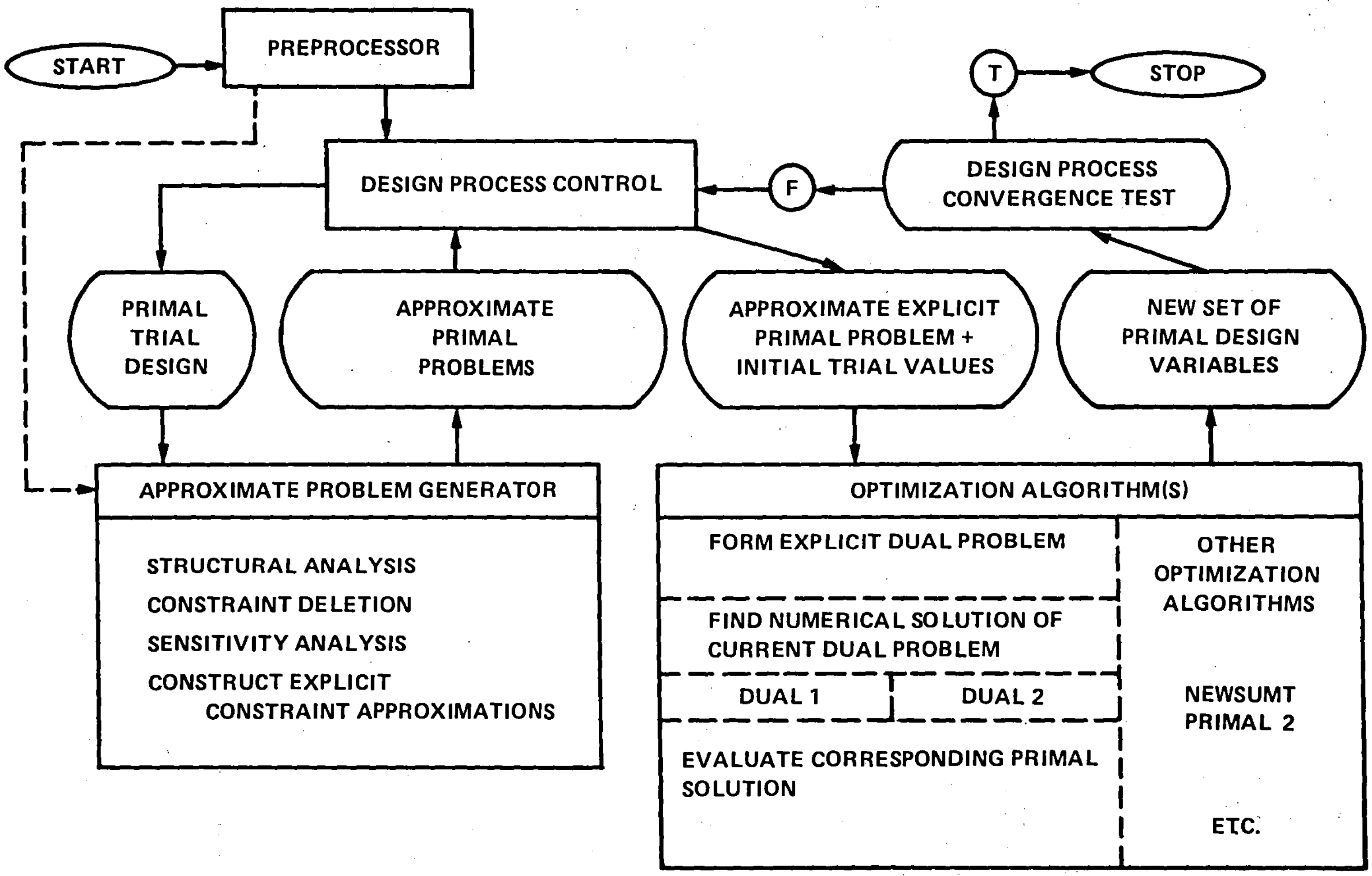

Figure 1. Basic Organization of ACCESS 3

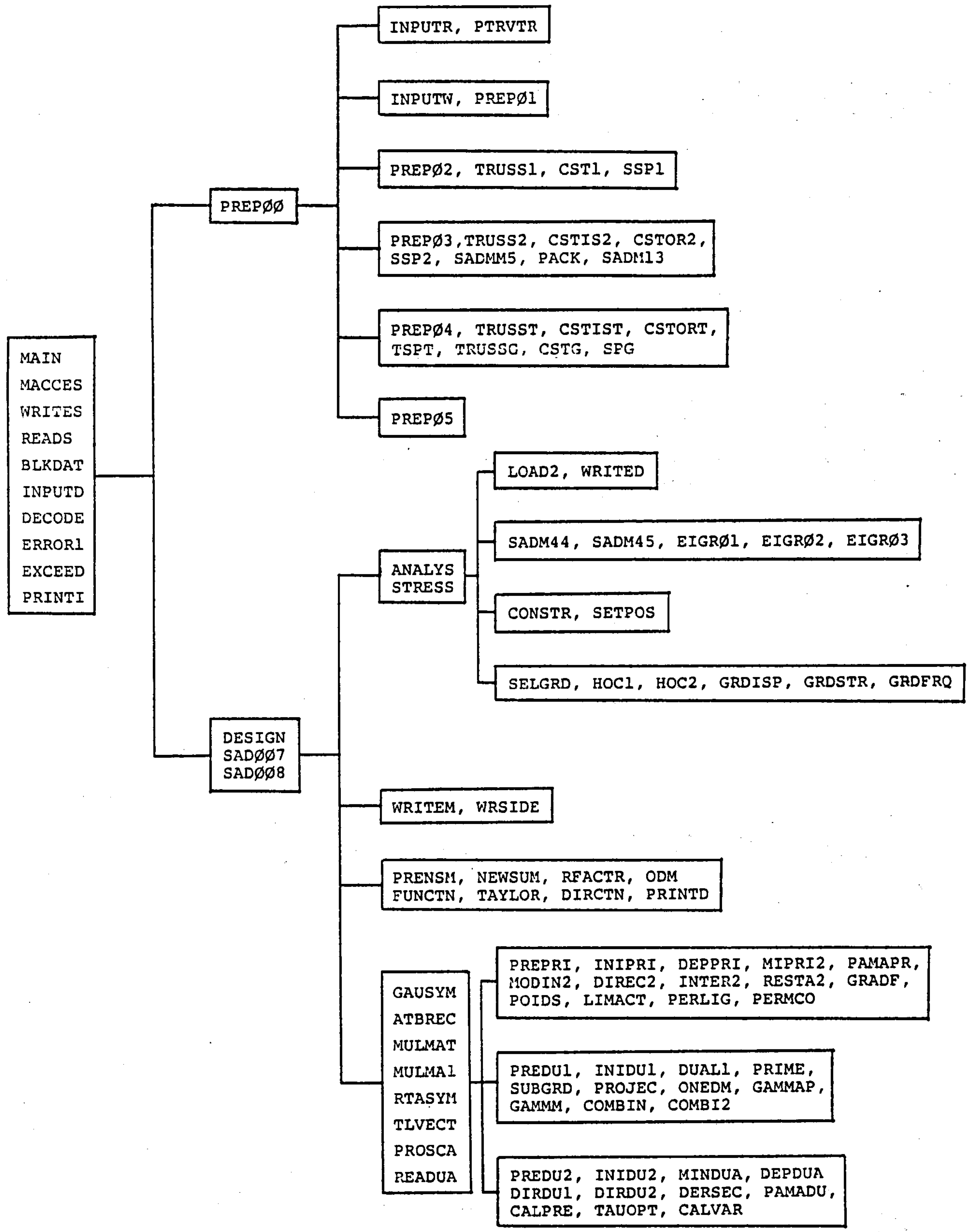

Fig. 2 Overlay Structure of ACCESS-3 (IBM version)

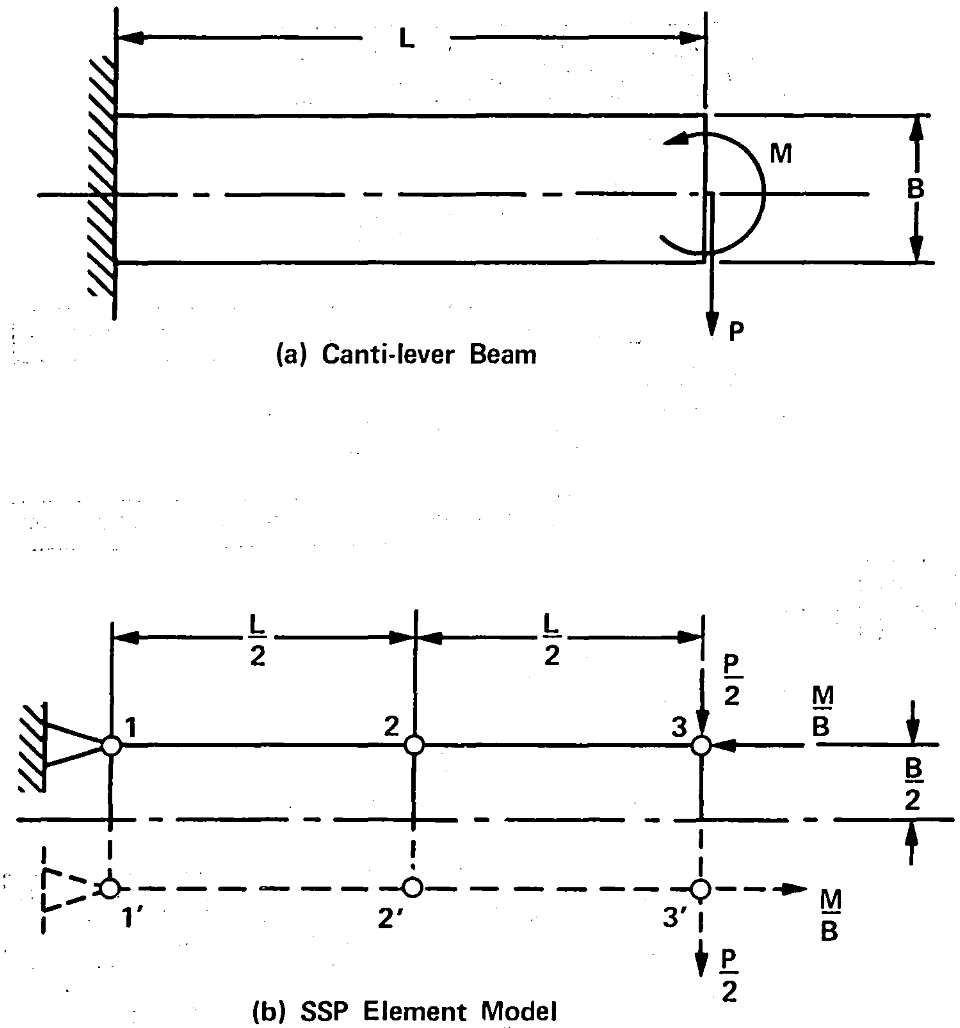

Figure 3. SSP Element Model Example

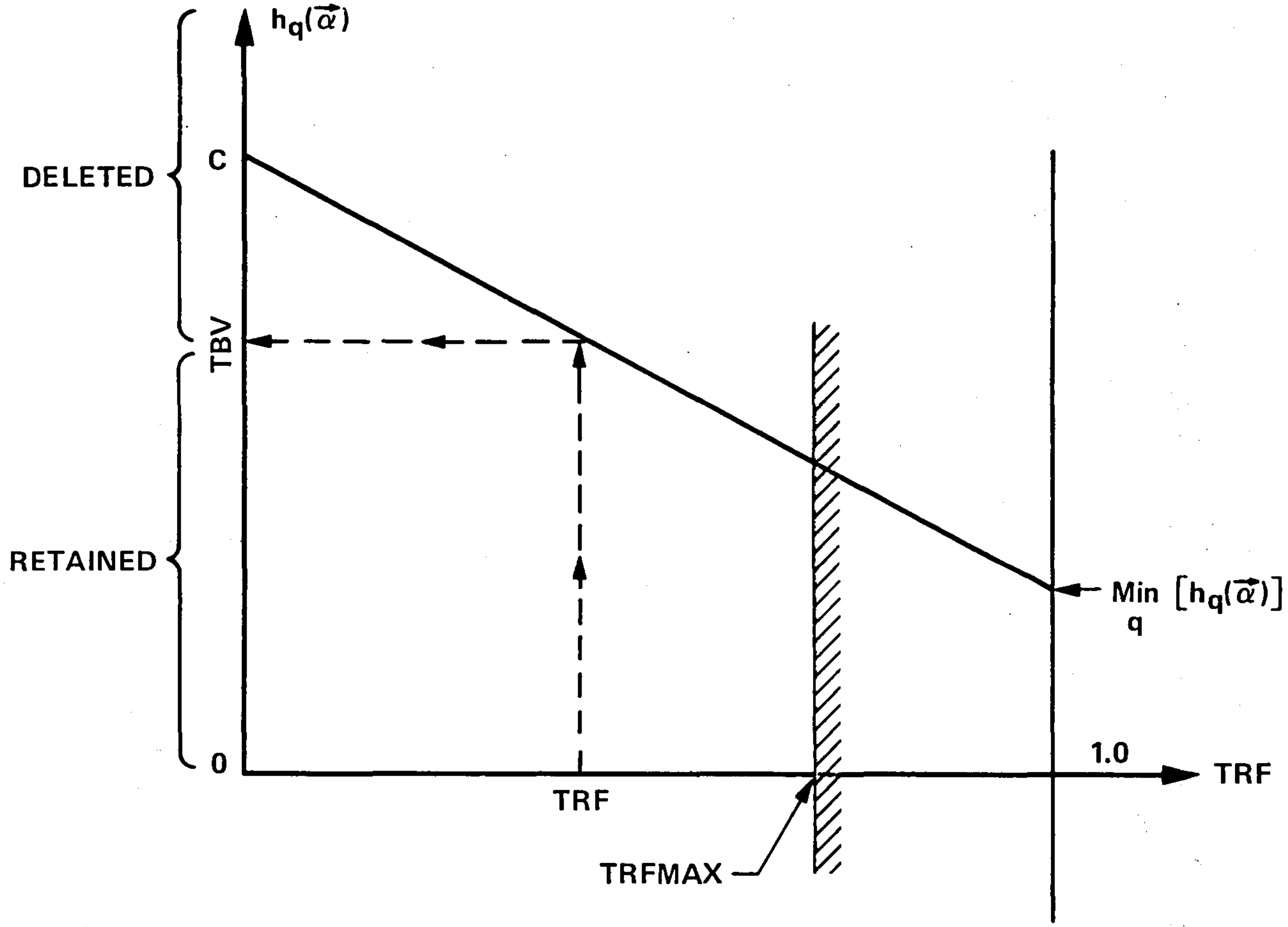

Figure 4. Truncation Boundary Value (TBV) vs. Truncation Factor (TRF)

Table 1. Temporary Files

File Name	Contents
10	Stiffness matrix components associated with unit values of independent design variables and load vector components which are independent of design variables
11	Mass matrix components associated with unit values of independent design variables
12	Load vector components due to thermal loads and dependent on independent design variables
13	Load vector components due to inertia loads and dependent on independent design variables
14	Constraint gradients
15	Input data and a part of preprocessor output
16	Thermal shear panel stiffness matrix components. Used only when IETP(6)≠0
17	Constraint gradients (except stress constraints). Required only when zero order approximation of the stress constraints is considered.
18	Eigenvector sensitivity vectors, if computed
19	Mass matrix post-multiplied by eigenvectors. Required only when second order expansion of frequency constraints is used.
20	Original system stiffness and mass matrices. Required only when second order expansion of frequency constraints is used.
21	Modified $[K-\lambda_i M]$ in the eigenvector sensitivity computation. Stored in decomposed form.
22	$\left(\frac{\partial K}{\partial \alpha_b} - \lambda_i \frac{\partial M}{\partial \alpha_b}\right)\bar{X}_i$, ((i=1, NEIG), b=1, B) Required only when second order expansion of frequency constraints is used.

Table 2. Required Blank Common Size

Problems	Elements	Total No. of Elements	Free Displ. d.o.f.s.	No. of Design Variables	Total No. of Constraints	Required Real Array	Required Integer Array
Wing Carry-Through Truss Model (Static)	TRUSS	63	42	63	256	4291	1606
Swept Wing (Metal) (Static)	CST SSP	60 70	120	18	268	5238	2305
Delta Wing-Composite (Static & Dynamic)	CSTOR	252 70	105	60	2661	13090	9433
Delta Wing-Composite (Static, Thermal and Dynamic)	CSTOR SSP TSP	252 70 70	105	60	2661	18652	9103
Delta Wing-Composite (Static, Thermal, Dynamic, discrete variables)	CSTOR SSP TSP	252 70 70	105	60 {12 continuous 48 discrete	2661	22327	8567

Table 3. Available Options for Frequency Constraints

Algorithm \ $\lambda=\omega^2$ Approx.	1st order Reciprocal DV's	1st order Direct DV's	2nd order Direct DV's
NEWSUMT	*	*	*
PRIMAL2	*	-	-
DUAL1	*	-	-
DUAL2	*	-	-

*available combination in ACCESS-3 program

Table 4. Algorithm Options for Various Kinds of Problems

Algorithm \ Kinds of DV's	Pure Continuous	Pure Discrete	Mixed Continuous - Discrete
NEWSUMT	*	-	-
PRIMAL2	*	-	-
DUAL1	*	*	*
DUAL2	*	-	-

* available for application in ACCESS-3 program

Table 5 Analysis Printout Control - IPRINT

All messages above the horizontal line corresponding to each value of IPRINT are printed

IPRINT	Information Printed
	Constraint identification code Posture table at each stage Time statistics of the job Messages prior to any error termination
0	
	Input data in readable format Initial and final nodal displacements Initial and final eigenanalysis results
1	
	Element sizes and weight information Scaling factor and scaled weight New list of linearized constraints (after zero order stress approximation) Independent linked design variable values (including lower and upper limits) Modified truncation factors Initial and final element stresses Initial and final values of all constraints
2*	
	Element stresses and constraint values at each stage Lower limits, upper limits and allowable discrete values after design variable normalization Interface data (with optimizer)
3	
	Listing of data cards Element geometry data Load vectors Gradients of retained constraints
4	
	Element stiffness/mass matrices Master stiffness/mass matrices Integer and real pointer vectors for dynamic array allocation Debugging of integer and real arrays

* Standard Values

Table 6 NEWSUMT Optimizer Printout Control - JPRINT

All messages above the horizontal line corresponding to each value of JPRINT are printed

JPRINT	Information Printed
	Control and system parameters Initial design analysis results Response surface penalty multipliers ODM's results summary Final results of optimization Time and counting statistics
0*	
	Results for each response surface
1	
	Direction finding data
2	
	ODM's results at each design point Golden section search data
3	
	Penalty function detailed data

* Standard value

Table 7 PRIMAL2 Optimizer Printout Control - JPRINT

All messages above the horizontal line corresponding to each value of JPRINT are printed

JPRINT	Information Printed
	Initial and final results summary
0*	
	Final values of all linear constraints and associated dual variables Identification of each constraint added to or dropped from the active set.
1	
	Final design variables ODM's results summary Active set strategy data
2	
	Design variables and search directions

* Standard value

Table 8 DUAL1 Optimizer Printout Control - JPRINT

All messages above the horizontal line corresponding to each value of JPRINT are printed

JPRINT	Information Printed
	Control and system parameters Final results summary
0*	
	Final dual variable values Summary of dual solution analysis (discrete case) Results in brief summary form (each restart)
1	
	Initial dual variable values (each restart) Final primal variable and constraint values Analysis of upper and lower bound solutions (discrete case) Results in brief summary form (each ODM)
2	
	Initial primal variable and constraint values (each restart) List of best discrete solutions
3	
	Primal and dual variable values (each ODM) Search direction and sensitivity of primal variables in ODM Newton iteration results
4	
	Detailed ODM's data
5	
	Detailed Newton iterations data

* Standard value

Table 9 DUAL2 Optimizer Printout Control - JPRINT

All messages above the horizontal line corresponding to each value of JPRINT are printed

JPRINT	Information Printed
0*	Final results summary
	Identification of the starting point (first stage only) Final values of all dual variables and associated primal constraints Identification of the dual subspace at each iteration
1	
	Final primal variable values Summary of results after each iteration
2	
	Data on search of a suitable dual starting point (first stage only) Search direction and dual variables at each iteration ODM's results
3	
	Primal variable values after each iteration

* Standard value

APPENDIX A

ELEMENT LIBRARY

Currently, 6 element types are available: they are TRUSS, CSTIS, CSTOR, SSP, PSP and TSP. Basic characteristics of these elements are given in the sequel.

1. Type 1 - TRUSS : Pin jointed bar element of uniform cross section

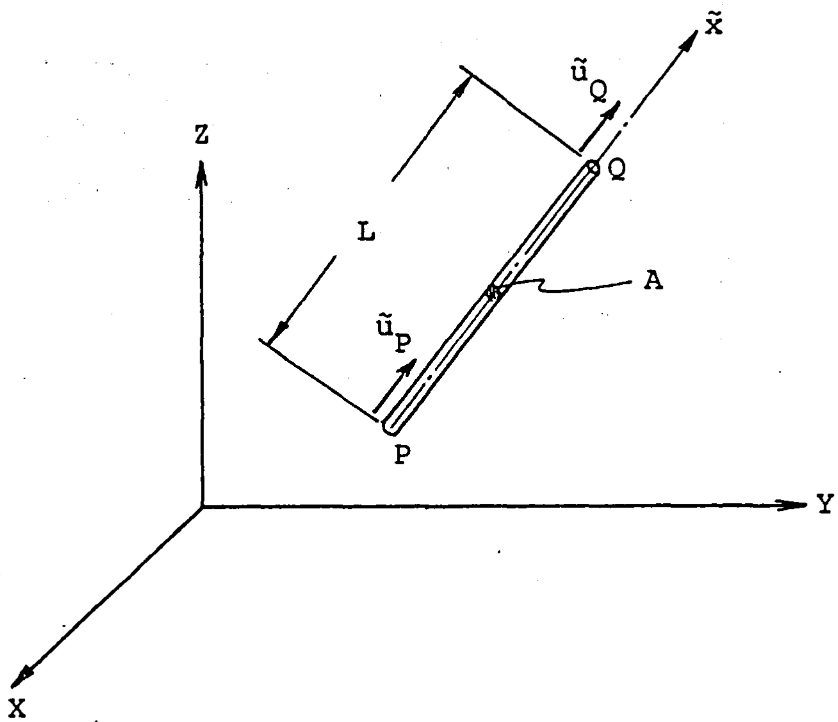

Fig. A-1 Space Truss Element

Strain-Displacement Relation (local coordinate)

$$\varepsilon = \frac{1}{L} [-1 \quad 1] \begin{Bmatrix} \tilde{u}_P \\ \tilde{u}_Q \end{Bmatrix} \tag{A-1}$$

Stress Strain Relation (local coordinate)

$$\sigma = E\,\varepsilon - E\alpha\Delta T \tag{A-2}$$

where α : thermal expansion coefficient

ΔT : average temperature change

Force Displacement Relation (local coordinate)

$$\frac{EA}{L}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}\begin{Bmatrix} \tilde{u}_P \\ \tilde{u}_Q \end{Bmatrix} - E\alpha\Delta TA\begin{Bmatrix} -1 \\ 1 \end{Bmatrix} - \begin{Bmatrix} \tilde{f}_P \\ \tilde{f}_Q \end{Bmatrix} = 0 \tag{A-3}$$

where F_p, F_q are externally applied force at P and Q nodes, respectively.

Force Displacement Relation (reference coordinates)

$$\frac{EA}{L}\begin{bmatrix} \ell^2 & \ell m & \ell n & -\ell^2 & -\ell m & -\ell n \\ & m^2 & mn & -\ell m & -m^2 & -mn \\ & & n^2 & -\ell n & -mn & -n^2 \\ & & & \ell^2 & \ell m & \ell n \\ & \text{Symm} & & & m^2 & mn \\ & & & & & n^2 \end{bmatrix}\begin{Bmatrix} U_P \\ V_P \\ W_P \\ U_Q \\ V_Q \\ W_Q \end{Bmatrix}$$

$$= -E\alpha\Delta TA\begin{Bmatrix} \ell \\ m \\ n \\ -\ell \\ -m \\ -m \end{Bmatrix} + \begin{Bmatrix} X_P \\ Y_P \\ Z_P \\ X_Q \\ Y_Q \\ Z_Q \end{Bmatrix} \tag{A.4}$$

Consistent Mass Matrix (reference coordinates)

$$[M] = \frac{\rho A L}{6} \begin{bmatrix} 2 & 0 & 0 & 1 & 0 & 0 \\ & 2 & 0 & 0 & 1 & 0 \\ & & 2 & 0 & 0 & 1 \\ & & & 2 & 0 & 0 \\ & \text{Sym} & & & 2 & 0 \\ & & & & & 2 \end{bmatrix} \qquad \text{(A-5)}$$

where ρ : density

2. <u>Type 2 - CSTIS:</u> Constant strain triangular membrane element with uniform thickness and isotropic material

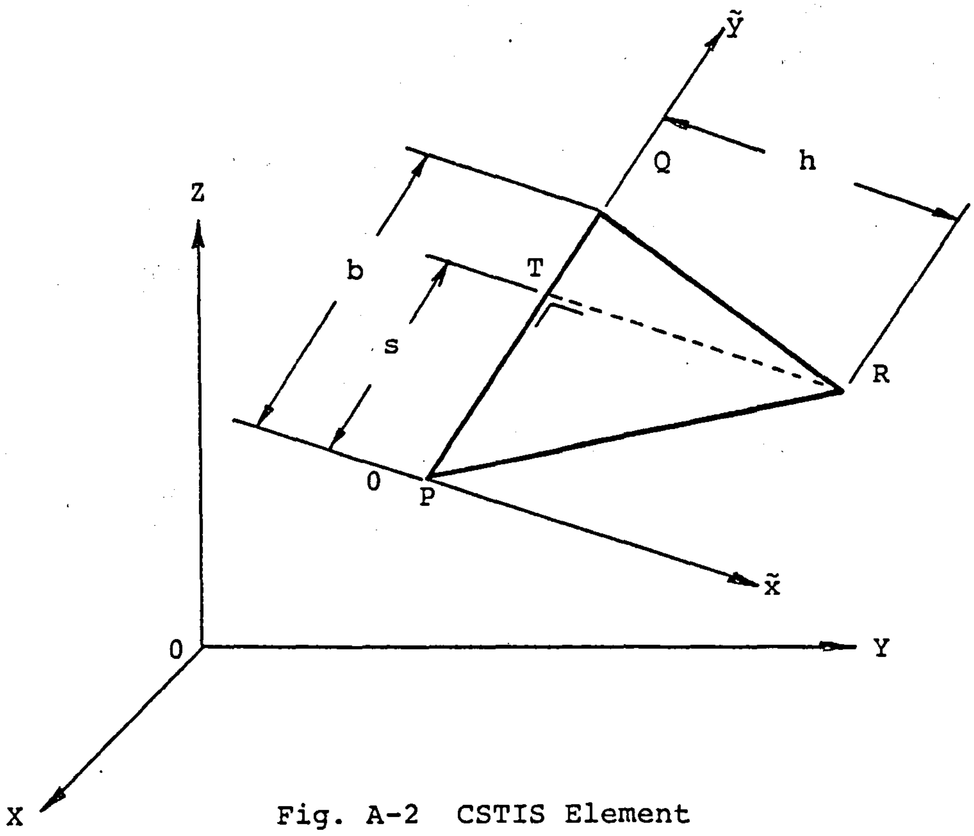

Fig. A-2 CSTIS Element

<u>Strain-Displacement Relation</u> (local coordinate)

$$\begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} = \frac{1}{bh} \begin{bmatrix} (s-b) & 0 & -s & 0 & b & 0 \\ 0 & -h & 0 & h & 0 & 0 \\ -h & (s-b) & h & -s & 0 & b \end{bmatrix} \begin{Bmatrix} \tilde{u}_P \\ \tilde{v}_P \\ \tilde{w}_P \\ \tilde{u}_Q \\ \tilde{v}_Q \\ \tilde{w}_Q \end{Bmatrix} \qquad \text{(A-6)}$$

Stress-Strain Relation (local coordinate)

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \gamma_{xy} \end{Bmatrix} = \frac{E}{1-\nu^2} \begin{bmatrix} 1 & \nu & 0 \\ \nu & 1 & 0 \\ 0 & 0 & \frac{1-\nu}{2} \end{bmatrix} \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} - \frac{E\alpha\Delta T}{1-\nu} \begin{Bmatrix} 1 \\ 1 \\ 1 \end{Bmatrix} \tag{A-7}$$

Stress-Displacement Relation (local coordinate)

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} = \frac{E}{bh(1-\nu^2)} \begin{bmatrix} (s-b) & -\nu h & -s & \nu h & b & 0 \\ \nu(s-b) & -h & -\nu s & h & \nu b & 0 \\ \frac{-(1-\nu)h}{2} & \frac{(1-\nu)(s-b)}{2} & \frac{(1-\nu)h}{2} & \frac{-(1-\nu)s}{2} & 0 & \frac{(1-\nu)b}{2} \end{bmatrix} \begin{Bmatrix} \tilde{u}_P \\ \tilde{v}_P \\ \tilde{w}_P \\ \tilde{u}_Q \\ \tilde{v}_Q \\ \tilde{w}_Q \end{Bmatrix}$$

$$- \frac{E\alpha\Delta T}{1-\nu} \begin{Bmatrix} 1 \\ 1 \\ 0 \end{Bmatrix} \tag{A-8}$$

Local-Reference Displacement Relation

$$\begin{Bmatrix} \tilde{u}_P \\ \tilde{v}_P \\ \tilde{u}_Q \\ \tilde{v}_Q \\ \tilde{u}_R \\ \tilde{v}_R \end{Bmatrix} = \begin{Bmatrix} \vec{\lambda}_x^{\,T} \cdot \vec{U}_P \\ \vec{\lambda}_y^{\,T} \cdot \vec{U}_P \\ \vec{\lambda}_x^{\,T} \cdot \vec{U}_Q \\ \vec{\lambda}_y^{\,T} \cdot \vec{U}_Q \\ \vec{\lambda}_x^{\,T} \cdot \vec{U}_R \\ \vec{\lambda}_y^{\,T} \cdot \vec{U}_R \end{Bmatrix} \quad \text{or } \tilde{u} = [T]\vec{U} \tag{A-9}$$

where $\vec{\lambda}_x$: unit vector parallel to the x-axis

$\vec{\lambda}_y$: unit vector parallel to the y-axis

U_P, U_Q, U_R : displacement vectors of P,Q,R nodes.

$$[T] = \begin{bmatrix} \ell_x & m_x & n_x & & & & & & \\ \ell_y & m_y & n_y & & 0 & & & 0 & \\ & & & \ell_x & m_x & n_x & & & \\ & 0 & & \ell_y & m_y & n_y & & 0 & \\ & & & & & & \ell_x & m_x & n_x \\ & 0 & & & 0 & & \ell_y & m_y & n_y \end{bmatrix} \tag{A-10}$$

<u>Stiffness Matrix</u> (local coordinate system)

$$K = K_n + K_s \tag{A-11}$$

where

$$K_n = \frac{Et}{4A(1-\nu^2)} \begin{bmatrix} (s-b)^2 & -\nu(s-b)h & -(s-b)s & \nu(s-b)h & (s-b)b & 0 \\ & h^2 & \nu hs & -h^2 & -\nu hb & 0 \\ & & s^2 & -\nu hs & -bs & 0 \\ & \text{Symm.} & & h^2 & \nu bh & 0 \\ & & & & b^2 & 0 \\ & & & & & 0 \end{bmatrix}$$

$$K_s = \frac{Et}{8A(1+\nu)} \begin{bmatrix} h^2 & -(s-b)h & -h^2 & hs & 0 & -bh \\ & (s-b)^2 & (s-b)h & -(s-b)s & 0 & (s-b)b \\ & & h^2 & -hs & 0 & bh \\ & & & s^2 & 0 & -bs \\ & & & & 0 & 0 \\ & \text{Symm.} & & & & b^2 \end{bmatrix}$$

<u>Force-Displacement Relation</u> (local coordinates)

$$K\,\tilde{u} + \frac{E\alpha\Delta Tt}{2(1-\nu)} \begin{Bmatrix} b-s \\ h \\ s \\ -h \\ -b \\ 0 \end{Bmatrix} = \tilde{f} \qquad \text{(A-12)}$$

<u>Consistent Mass Matrix</u>

$$[M] = \frac{\rho At}{12} \begin{bmatrix} 2 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ & 2 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ & & 2 & 0 & 0 & 1 & 0 & 0 & 1 \\ & & & 2 & 0 & 0 & 1 & 0 & 0 \\ & \text{Symm.} & & & 2 & 0 & 0 & 1 & 0 \\ & & & & & 2 & 0 & 0 & 1 \\ & & & & & & 2 & 0 & 0 \\ & & & & & & & 2 & 0 \\ & & & & & & & & 2 \end{bmatrix} \qquad \text{(A-13)}$$

where ρ : density

3. <u>Type 3 - CSTOR:</u> Constant strain triangular membrane element with uniform thickness of an orthotropic material

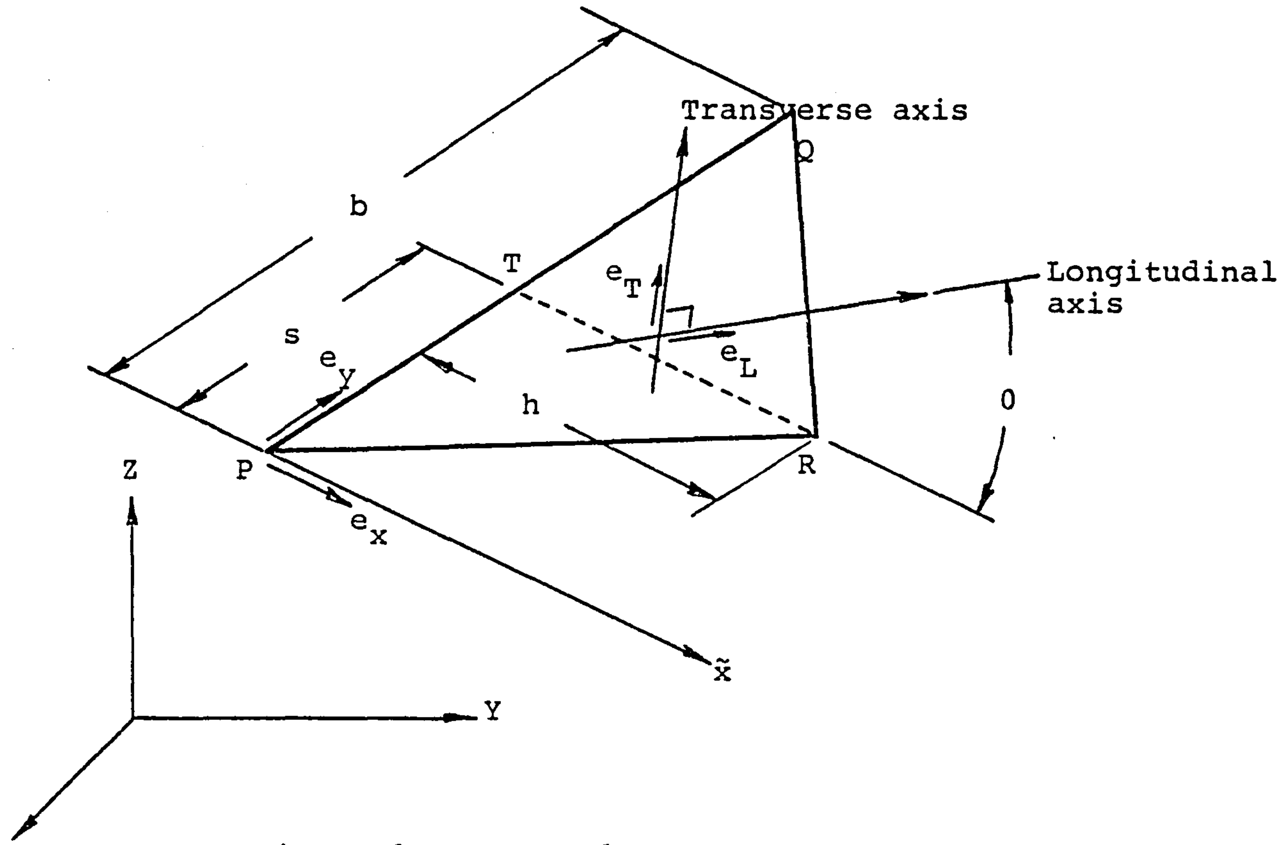

Fig. A-3 CSTOR Element

<u>Strain-Displacement Relation</u> (local coordinate)

$$\begin{Bmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \gamma_{xy} \end{Bmatrix} = \frac{1}{bh} \begin{bmatrix} (s-b) & 0 & -s & 0 & b & 0 \\ 0 & -h & 0 & h & 0 & o \\ -h & (s-b) & h & -s & 0 & b \end{bmatrix} \begin{Bmatrix} \tilde{u}_P \\ \tilde{v}_P \\ \tilde{u}_Q \\ \tilde{v}_Q \\ \tilde{u}_R \\ \tilde{v}_R \end{Bmatrix} \qquad \text{(A-14)}$$

$$= [B]\ \tilde{u}$$

Stress-Strain Relation (material axis)

$$\begin{Bmatrix} \sigma_{LL} \\ \sigma_{TT} \\ \gamma_{LT} \end{Bmatrix} = \underbrace{\begin{bmatrix} \dfrac{E_L}{1-\nu_{LT}\nu_{TL}} & \dfrac{\nu_{TL}E_L}{1-\nu_{LT}\nu_{TL}} & 0 \\ \dfrac{\nu_{LT}E_T}{1-\nu_{LT}\nu_{TL}} & \dfrac{E_T}{1-\nu_{LT}\nu_{TL}} & 0 \\ 0 & 0 & G_{LT} \end{bmatrix}}_{[D]} \begin{Bmatrix} \varepsilon_{LL} \\ \varepsilon_{TT} \\ \gamma_{LT} \end{Bmatrix} - \Delta T \underbrace{\begin{Bmatrix} \dfrac{E_L(\alpha_L+\nu_{TL}\alpha_T)}{1-\nu_{LT}\nu_{TL}} \\ \dfrac{E_T(\alpha_T+\nu_{LT}\alpha_L)}{1-\nu_{LT}\nu_{TL}} \\ 0 \end{Bmatrix}}_{\vec{h}} \qquad \text{(A-15)}$$

Strain Transformation Law (material-local)

$$\begin{Bmatrix} \varepsilon_{LL} \\ \varepsilon_{TT} \\ \gamma_{LT} \end{Bmatrix} = \underbrace{\begin{bmatrix} \ell_{Lx}^2 & \ell_{Ly}^2 & \ell_{Lx}\ell_{Ly} \\ \ell_{Tx}^2 & \ell_{Ty}^2 & \ell_{Tx}\ell_{Ty} \\ 2\ell_{Lx}\ell_{Tx} & 2\ell_{Ly}\ell_{Tx} & \ell_{Ly}\ell_{Tx}+\ell_{Ty}\ell_{Lx} \end{bmatrix}}_{[T]} \begin{Bmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \gamma_{xy} \end{Bmatrix} \qquad \text{(A-16)}$$

where $\ell_{Lx} = \vec{e}_L^T \cdot \vec{e}_x = \cos\theta$, $\ell_{Tx} = \vec{e}_T^T \cdot \vec{e}_x = -\sin$

$\ell_{Ly} = \vec{e}_L^T \cdot \vec{e}_y = \sin\theta$, $\ell_{Ty} = \vec{e}_T^T \cdot \vec{e}_y = \cos\theta$

Note: the direction of $\vec{e}_2$ is chosen so that

$(\vec{e}_1 \times \vec{e}_2) \cdot (\vec{e}_x \times \vec{e}_y) > 0.$

Stress-Displacement Relation

$$\begin{Bmatrix} \sigma_{LL} \\ \sigma_{TT} \\ \gamma_{LT} \end{Bmatrix} = [D][T][B]\,\tilde{u} - \Delta T \cdot \vec{h} \qquad \text{(A-17)}$$

Local-Reference Displacement Relation

same as type 2

Stiffness Matrix (local coordinate)

$$K = K_n + K_s \tag{A-18}$$

$$K_n = \frac{t}{2bh(1-\nu_{LT}\nu_{TL})}\begin{bmatrix} C_1(s-b)^2 & -C_2(s-b)h & -C_1(s-b)s & C_2(s-b)h & C_1(s-b)b & 0 \\ & C_2h^2 & C_2hs & -C_3h^2 & -C_2bh & 0 \\ & & C_1s^2 & -C_2hs & -C_1bs & 0 \\ & \text{Symm} & & C_2h^2 & C_2bh & 0 \\ & & & & C_1b^2 & 0 \\ & & & & & 0 \end{bmatrix} \tag{A-19}$$

where

$$C_1 = \rho^4 E_L + 2\rho^2\mu^2\nu_{LT}E_T + \mu^4E_T$$

$$C_2 = \rho^2\mu^2E_L + (\rho^4 + \mu^4)\nu_{LT}E_T + \rho^2\mu^2E_T$$

$$C_3 = \mu^4E_L + 2\rho^2\mu^2\nu_{LT}E_T + \rho^4E_T$$

$$\nu_{LT}E_T = \nu_{TL}E_L$$

$$\rho = \sin\theta$$

$$\mu = \cos\theta$$

$K_s =$

$$
\begin{bmatrix}
(s-b)^2 D_1 + 2h(s-b)D_2 + h^2 D_3 & & & & & \text{Symm.} \\
h(s-b)D_1 + [h^2-(s-b)^2]D_2 - h(s-b)D_3 & h^2 D_1 - 2h(s-b)D_2 + (s-b)^2 D_3 & & & & \\
-s(s-b)D_1 - (2s-b)hD_2 - h^2 D_3 & -hsD_1 [(s-b)s-h^2]D_2 + (s-b)h\, D_3 & s^2 D_1 + 2hsD_2 + h^2 D_3 & & & \\
-h(s-b)D_1 + [(s-b)s-h^2]D_2 + sh\, D_3 & -h^2 D_1 + h(2s-b)D_2 - s(s-b)D_3 & hsD_1 + (h^2-s^2)D^2 - hs\, D_3 & h^2 D_1 - 2hs\, D_2 + s^2 D_3 & & \\
b(s-b)D_1 + bh\, D_2 & bhD_1 - b(s-b)D_2 & -bsD_1 - bh\, D_2 & -bhD_1 + bs\, D_2 & b^2 D_1 & \\
-b(s-b)D_2 - bh\, D_3 & -bhD_2 + b(s-b)D_3 & bs\, D_2 + bh\, D_3 & bh\, D_2 - bs\, D_3 & -b^2 D_2 & b^2 D_3
\end{bmatrix}
\tag{A-20}
$$

where $D_1 = 4\rho^2\mu^2$

$D_2 = 2\rho\mu(\rho^2-\mu^2)$

$D_3 = (\rho^2-\mu^2)^2$

Equilibrium Equation (local coordinate)

$$K\,\tilde{u} + \vec{h} = \vec{f}$$

$$\vec{h} = t\,\Delta T \begin{Bmatrix} -(b-s)(\rho^2 h_1 + \mu^2 h_2) + 2h\rho\mu(h_1 - h_2) \\ -h(\mu^2 h_1 + \rho^2 h_2) + 2(b-s)\rho\mu(h_1 - h_2) \\ -s(\rho^2 h_1 + \mu^2 h_2) - 2h\rho\mu(h_1 - h_2) \\ h(\mu^2 h_1 + \rho^2 h_2) + 2s\rho\mu(h_1 - h_2) \\ b(\rho^2 h_1 + \mu^2 h_2) \\ -2b\rho\mu(h_1 - h_2) \end{Bmatrix} \qquad \text{(A-21)}$$

where

$$h_1 = -\frac{E_L(\alpha_L + \nu_{TL}\alpha_T)}{1-\nu_{LT}\nu_{TL}}$$

$$h_2 = -\frac{E_T(\alpha_T + \nu_{LT}\alpha_L)}{1-\nu_{LT}\nu_{TL}}$$

Consistent Mass Matrix (reference coordinate)

same as type 2

4. <u>Type 4 - SSP:</u> Symmetric shear panel element with uniform thickness and isotropic material

This is a special element used to model relatively thin symmetric structures such as idealized supersonic lifting surfaces. Theoretical discussion is given in Ref. 1. It is assumed that this element models the upper (or lower but not both) half of the symmetric structure and the element plane of symmetry coincides with the X-Y plane. It is further assumed that all SSP elements are placed vertically with respect to the X-Y reference coordinate plane.

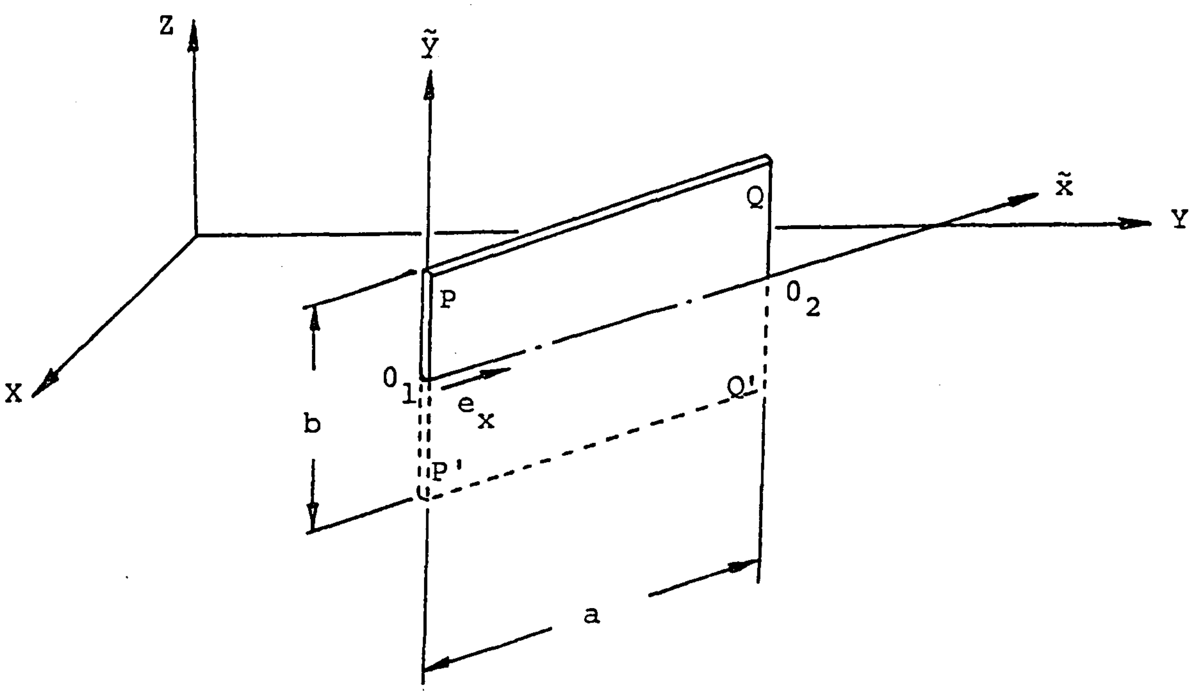

Fig. A-4 SSP Element

Note:

1. There are only two nodes per element.
2. The line of intersection with the XY plane does not move in the XY plane. It can only move vertically.

3. If the heights PP' and QQ' are different, the average (PP' + QQ')/2 is considered as the height of the element, i.e. b.

4. No thermal load can be considered in this element

Strain Displacement Relation (local coordinate)

$$\begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} = \begin{bmatrix} -\frac{2\eta}{a} & 0 & \frac{2\eta}{a} & 0 \\ \frac{2\nu\eta}{a} & 0 & \frac{2\nu\eta}{a} & 0 \\ \frac{1}{b} & -\frac{1}{a} & \frac{1}{b} & \frac{1}{a} \end{bmatrix} \begin{Bmatrix} \tilde{u}_P \\ \tilde{v}_P \\ \tilde{u}_Q \\ \tilde{v}_Q \end{Bmatrix} \qquad \text{(A-22)}$$

$$\tilde{\varepsilon} = [B]u$$

wherein $\eta = \tilde{Y}/b$

Stress-Strain Relation (local coordinate)

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} = \frac{E}{1-\nu^2} \begin{bmatrix} 1 & \nu & 0 \\ \nu & 1 & 0 \\ 0 & 0 & \frac{1-\nu}{2} \end{bmatrix} \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} \qquad \text{(A-23)}$$

Stress Displacement Relation (local coordinate)

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} = E \begin{bmatrix} -\frac{2\eta}{a} & 0 & \frac{2\eta}{a} & 0 \\ 0 & 0 & 0 & 0 \\ \frac{1}{2(1+\nu)b} & \frac{1}{2(1+\nu)a} & \frac{1}{2(1+\nu)b} & \frac{1}{2(1+\nu)a} \end{bmatrix} \begin{Bmatrix} \tilde{u}_P \\ \tilde{v}_P \\ \tilde{u}_Q \\ \tilde{v}_Q \end{Bmatrix} \qquad \text{(A-24)}$$

Local to Reference Displacement Transformation

$$\begin{Bmatrix} \tilde{u}_P \\ \tilde{v}_P \\ \tilde{u}_Q \\ \tilde{v}_Q \end{Bmatrix} = \begin{bmatrix} \ell_x & m_x & 0 & & 0 & \\ 0 & 0 & \pm 1^* & & & \\ & 0 & & \ell_x & m_x & 0 \\ & & & 0 & 0 & \pm 1^* \end{bmatrix} \begin{Bmatrix} U_P \\ V_P \\ W_P \\ U_Q \\ V_Q \\ W_Q \end{Bmatrix} \qquad \text{(A-25)}$$

*(-) sign if $Z_P < 0$ and $Z_Q < 0$

where ℓ_x and m_x are components of a unit vector $\vec{e}_x$ along the local $\tilde{x}$ axis.

Stiffness Matrix (local coordinate)

$$K = \frac{Et}{12(1+\nu)} \begin{bmatrix} F+3\alpha & -3 & -F+3\alpha & 3 \\ & 3/\alpha & -3 & -3/\alpha \\ \text{Symm.} & & F+3\alpha & 3 \\ & & & 3/\alpha \end{bmatrix} \qquad \text{(A-26)}$$

where $\alpha = \frac{a}{b}$

$$F = \frac{2(1+\nu)}{\alpha}$$

<u>Consistent Mass Matrix</u> (local coordinate)

$$M = \frac{\rho abt}{2}\begin{bmatrix} \frac{1}{9}+G & -\frac{1}{12}H & 0 & \frac{1}{18}-G & -\frac{1}{12}H & 0 \\ & \frac{1}{3} & 0 & \frac{1}{12}H & \frac{1}{6} & 0 \\ & & \frac{1}{9} & 0 & 0 & \frac{1}{18} \\ & & & \frac{1}{9}+G & \frac{1}{12}H & \frac{1}{3} \\ & \text{Symm.} & & & \frac{1}{3} & 0 \\ & & & & & \frac{1}{9} \end{bmatrix} \qquad \text{(A-27)}$$

where ρ = density

$$G = \frac{\alpha^2}{30} + \frac{\nu}{18} + \frac{\nu^2}{30\alpha^2}$$

$$H = \alpha + \frac{1}{\alpha}$$

It may look strange that the mass matrix depends upon Poisson's ratio ν through G. This is due to the fact that the assumed displacement field is derived based on assumed stress field.

5. Type 5 - PSP: Pure symmetric shear panel element with uniform thickness and isotropic material

This element is identical to a type 4 (SSP) element, except for a minor change in the assumed displacement state so that the stress state of the element is pure shear: i.e. $\sigma_x = \sigma_y \equiv 0$. This implies that $\varepsilon_x = \varepsilon_y \equiv 0$.

Strain Displacement Relation (local coordinate)

$$\gamma_{xy} = \left[\frac{1}{b}, -\frac{1}{a}, \frac{1}{b}, \frac{1}{a} \right] \left\{ \tilde{u}_P, \tilde{v}_P, \tilde{u}_Q, \tilde{v}_Q \right\}^T \tag{A-28}$$

Stress-Strain Relation (local coordinate)

$$\tau_{xy} = \frac{E}{2(1+\nu)} \gamma_{xy} \tag{A-29}$$

Stress-Displacement Relation

$$\tau_{xy} = \frac{E}{2(1+\nu)} \left[\frac{1}{b}, -\frac{1}{a}, \frac{1}{b}, \frac{1}{a} \right] \left\{ \tilde{u}_P, \tilde{v}_P, \tilde{u}_Q, \tilde{v}_Q \right\}^T \tag{A-30}$$

Local to Reference Displacement Transformation

same as type 4.

Stiffness Matrix (local coordinate)

same as type 4 except $F \equiv 0$.

Mass Matrix

Assumed to be the same as type 4.

<u>Strain-Displacement Relation</u> (local coordinates)

$$\begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} = \begin{bmatrix} -\frac{1}{a} & -\frac{\nu}{b}(1-\frac{2x}{a}) & \frac{1}{a} & \frac{\nu}{b}(1-\frac{2x}{a}) \\ 0 & \frac{2}{b}(1-\frac{x}{a}) & 0 & \frac{2x}{ab} \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{Bmatrix} \tilde{u}_P \\ \tilde{v}_P \\ \tilde{u}_Q \\ \tilde{v}_Q \end{Bmatrix} \qquad \text{(A-31)}$$

<u>Stress-Strain Relation</u>

$$\begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} = \frac{E}{1-\nu^2} \begin{bmatrix} 1 & \nu & 0 \\ \nu & 1 & 0 \\ 0 & 0 & \frac{1+\nu}{2} \end{bmatrix} \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} - \frac{E\alpha\Delta T}{1-\nu} \begin{Bmatrix} 1 \\ 1 \\ 0 \end{Bmatrix} \qquad \text{(A-32)}$$

<u>Stress-Displacement Relation</u>

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \gamma_{xy} \end{Bmatrix} = \frac{E}{1-\nu^2} \left[\begin{array}{c|c|c|c} -\frac{1}{a} & \frac{\nu}{b} & \frac{1}{a} & \frac{\nu}{b} \\ \hline -\frac{\nu}{a} & \frac{1}{b}[2-\nu^2-\frac{2(1-\nu^2)}{a}x] & \frac{\nu}{a} & \frac{1}{b}[\nu^2+\frac{2(1-\nu^2)}{a}x] \\ \hline 0 & 0 & 0 & 0 \end{array}\right] \begin{Bmatrix} u_P \\ v_P \\ u_Q \\ v_Q \end{Bmatrix}$$

$$- \frac{E\alpha\Delta T}{1-\nu} \begin{Bmatrix} 1 \\ 1 \\ 0 \end{Bmatrix} \qquad \text{(A-33)}$$

<u>Local to reference displacement transformation</u>

same as type 4

Stiffness Matrix (local coordinate

$$K = \frac{Et}{2(1-\nu^2)} \begin{bmatrix} \frac{1}{\alpha} & -\nu & -\frac{1}{\alpha} & -\nu \\ & \frac{4-\nu^2}{3}\alpha & \nu & \frac{2+\nu^2}{3}\alpha \\ & & \frac{1}{\alpha} & \nu \\ \text{Symm.} & & & \frac{4-\nu^2}{3}\alpha \end{bmatrix} \begin{Bmatrix} \tilde{u}_P \\ \tilde{v}_P \\ \tilde{u}_Q \\ \tilde{v}_Q \end{Bmatrix} \tag{A-34}$$

where $\alpha = \frac{a}{b}$

Force Displacement Relation (local coordinate)

$$K\,\tilde{u} - \frac{E\alpha\Delta T\ t}{2(1-\nu)} \begin{Bmatrix} -b \\ a \\ b \\ a \end{Bmatrix} = \tilde{f} \tag{A-35}$$

Consistent Mass Matrix

Assumed to be the same as type 4

Note: As shown in the stress-displacement relation, stress distribution is linear with respect to x. In order to simplify the problem, an approximate stress displacement relation is used in computing stress and stress sensitivity.

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \end{Bmatrix}_{\text{approx.}} = \frac{E}{1-\nu^2} \begin{bmatrix} -\frac{1}{a} & \frac{\nu}{b} & \frac{1}{a} & \frac{\nu}{b} \\ -\frac{\nu}{a} & \frac{1}{b} & \frac{\nu}{a} & \frac{1}{b} \end{bmatrix} \begin{Bmatrix} \tilde{u}_P \\ \tilde{v}_P \\ \tilde{u}_Q \\ \tilde{v}_Q \end{Bmatrix} - \frac{E\alpha\Delta T}{1-\nu} \begin{Bmatrix} 1 \\ 1 \end{Bmatrix} \qquad \text{(A-36)}$$

6. <u>Type 6 - TSP:</u> Thermal symmetric shear panel element with uniform thickness and isotropic material

Since SSP and PSP cannot be used for problems involving thermal loads, this special element is added to the ACCESS-3 element library. The TSP element is designed to be used under steady thermal soak load conditions such that the temperature change in each TSP element is uniform and therefore symmetric with respect to the X-Y plane.

If the structure is subject to both mechanical and thermal loads, two structural models must be created and analyzed separately. One model is to use SSP elements to model shear panels and it is subject to only mechanical loads. The other model uses TSP elements to model the shear panels and it is subject to only thermal soak loads. These two models are created automatically, if the user specifies both SSP and TSP elements. Displacement and stress states of the structure subject to both thermal and mechanical loads are generated by superimposing the results obtained from the two separate models.

Theoretically, it is also possible to consider the PSP - TSP element combination, but this is not implemented in the current version of the program.

Note that the TSP option requires a significant amount of core memory and CPU time, since two system stiffness matrices are stored and decomposed. Sensitivity analyses of the responses must be carried out separately and superimposed afterwards. Therefore, analysis effort is nearly doubled when thermal effects need to be considered.

Appendix B

Examples

Two simple examples are given to illustrate input data preparation and program output for various features of the ACCESS 3 code. To help understand these examples, Figs. B1 and B2 represent the geometrical layout of the structures and the following indications are provided:

(1) 10-bar cantilever truss

- static constraints only;
- automatic selection of stress constraints requiring first order approximation;
- equality constraints on displacement;
- DUAL 2 optimizer

Note that displacements at nodes 4 and 5 in the Y direction are required to be equal to -5.08 cm (-2.0 in) and -2.54 cm (-1.0 in), respectively.

(2) 10 element delta wing

- static constraints and frequency constraint;
- mechanical and thermal loads;
- mixed continuous-discrete problem;
- titanium webs (continuous) and composite skin (discrete);
- DUAL 1 optimizer.

Note that the available discrete thicknesses for the CSTOR elements are {0.0254, 0.0508, 0.0762, 0.1016,....5.08} (cm) or {0.01, 0.02, 0.03, 0.04,....2.0} (in).

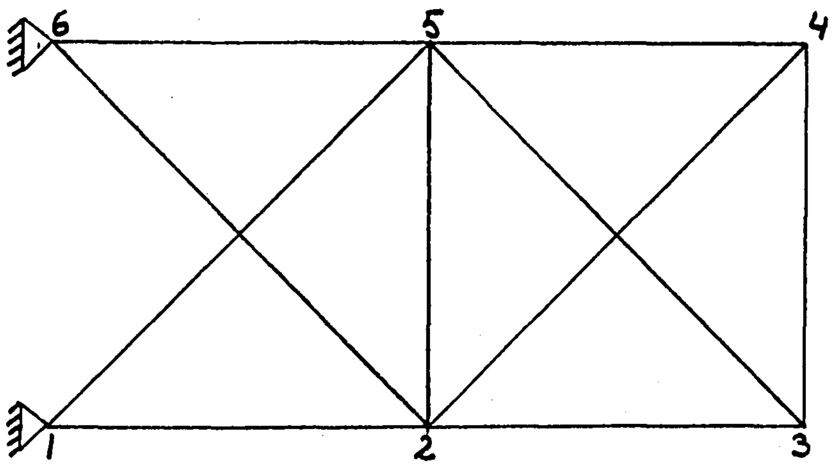

Fig. B1 10 bar cantilever truss

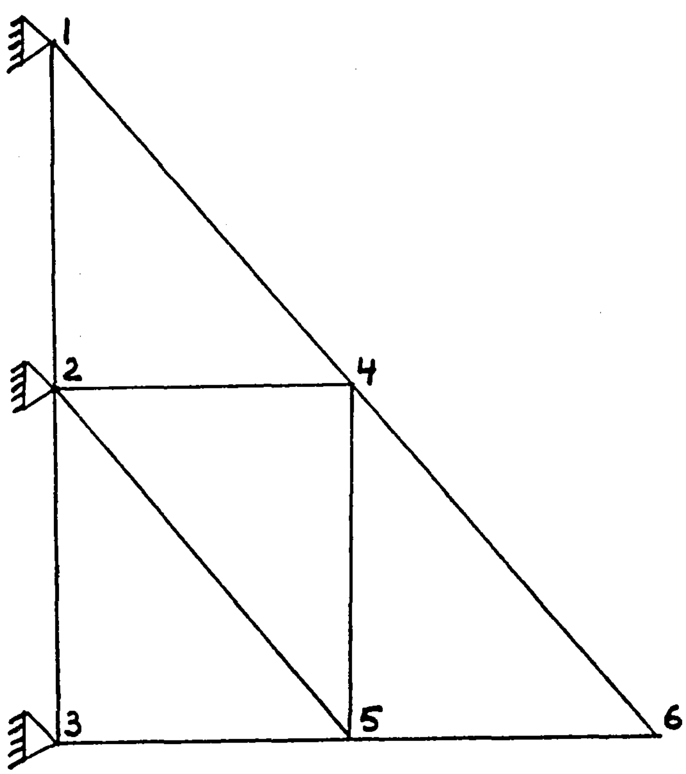

Fig. B2 10 element delta wing

(1) <u>10 bar cantilever truss</u>

```
 TEN BAR TRUSS  -  EQUALITY CONSTRAINTS
1TEST FOR DUAL ALGORITHMS IN ACCESS3
    7    2    0    1    1    0    0    0    0
    6    6    1    1    0    1    1    0    0    0    0
   10
    1         0.0       0.0
    2         0.3600E3  0.0
    3         0.7200E3  0.0
    4         0.7200E3  0.3600E3
    5         0.3600E3  0.3600E3
    6         0.0       0.3600E3
    1    1    1    1
    2    0    0    1
    3    0    0    1
    4    0    0    1
    5    0    0    1
    6    1    1    1
    1
    1    1    2    0    0    1    1    1    0    1   -1
    2    2    3    0    0    2    1    1    0    1   -1
    3    3    4    0    0    3    1    1    0    1   -1
    4    4    5    0    0    4    1    1    0    1   -1
    5    5    6    0    0    5    1    1    0    1   -1
    6    2    5    0    0    6    1    1    0    1   -1
    7    1    5    0    0    7    1    1    0    1   -1
    8    2    6    0    0    8    1    1    0    1   -1
    9    2    4    0    0    9    1    1    0    1   -1
   10    3    5    0    0   10    1    1    0    1   -1
 20.0
  0.1
  0.1000E8  0.3000E0  0.1000E0  0.0000E0 -0.2500E5  0.2500E5
    2
    2         0.0000E0 -0.1000E6
    3         0.0000E0 -0.1000E6
    0    0                                        INERTIA
    0    0                                        FLIGHT
    0                                             MASS
  0.1000E0  0.1000E0  1.0000E0
    2                                             DISPL.
  0.1000E0  0.8000E0  1.0000E0  1.2000E0  0.01
    4    2    2      -2.0      -2.0
    5    2    2      -1.0      -1.0
    0                                             SLOPE
    3                                             STRESS
  0.1000E0  0.8000E0  1.0000E0  1.2000E0  C.1000E4   0.1
    0                                             FREQU.
    0                                             FLUTTER
    1   10
  0.0001E0  0.0001E0  0.0000E0  0.0000E0  1.0000E3
  1.0000E0  1.2000E0 -0.01
  2
    5    10   15   20   25   30   35   40   45   50   55   60   65
```

TEN BAR TRUSS - EQUALITY CONSTRAINTS
TEST FOR DUAL ALGORITHMS IN ACCESS3

COMPLETE OPTIMIZATION BY DUAL2 OPTIMIZER

ANALYSIS PRINT OUT CONTROL = 2

DESIGN IN LINKED SIZING VARIABLE SPACE

NUMBER OF NODES	6
NUMBER OF TOTAL ELEMENTS	10
NUMBER OF LINKED VARIABLES	10
NUMBER OF LOAD CONDITIONS	1
NUMBER OF BOUNDARY NODES	6
NUMBER OF ISOTROPIC MATERIALS	1
NUMBER OF ORTHOTROPIC MATERIALS	0

	TRUSS	CST ISOTROPIC	CST ORTHOTROPIC	SSP	PSP	TSP	TBD	TBD	TBD	TBD
ELEMENTS	10									
LINKED VARIABLES	10									

NODE NUMBER	X	Y	Z
1	0.0	0.0	0.0
2	360.0000	0.0	0.0
3	720.0000	0.0	0.0
4	720.0000	360.0000	0.0
5	360.0000	360.0000	0.0
6	0.0	360.0000	0.0

DISPLACEMENT BOUNDARY CONDITIONS

NODE NO.	BOUNDARY CODES* X	Y	Z	PRESCRIBED DISPLACEMENT X	Y	Z
1	1	1	1	0.0	0.0	0.0
2	0	0	1	0.0	0.0	0.0
3	0	0	1	0.0	0.0	0.0
4	0	0	1	0.0	0.0	0.0
5	0	0	1	0.0	0.0	0.0
6	1	1	1	0.0	0.0	0.0

* -1=PRESCRIBED, 0=FREE, 1=FIXED

ELEMENT NO.	NODE NUMBERS N1	N2	N3	N4	LINKED GROUP	ELEMENT SIZE INITIAL	LOW.BD	UPP.BD	MATERIAL GROUP	SIDE CONSTRAINT CODE*	
TRUSS ELEMENTS											
1	1	2			1	20.000000	0.100000	0.100000	1	-1	0
2	2	3			2	20.000000	0.100000	0.100000	1	-1	0
3	3	4			3	20.000000	0.100000	0.100000	1	-1	0
4	4	5			4	20.000000	0.100000	0.100000	1	-1	0
5	5	6			5	20.000000	0.100000	0.100000	1	-1	0
6	2	5			6	20.000000	0.100000	0.100000	1	-1	0
7	1	5			7	20.000000	0.100000	0.100000	1	-1	0
8	2	6			8	20.000000	0.100000	0.100000	1	-1	0
9	2	4			9	20.000000	0.100000	0.100000	1	-1	0
10	3	5			10	20.000000	0.100000	0.100000	1	-1	0

* -2=FIXED AT INITIAL VALUE -1=LOWER BOUNDS ONLY
0=NON NEGATIVITY ONLY 1=UPPER BOUNDS ONLY
2=BOTH UPPER AND LOWER BOUNDS
SECOND NUMBER = DISCRETE VALUE GROUP NUMBER

MATERIAL CONSTANTS - ISOTROPIC MATERIALS

ELEMENT NO.	NODE NUMBERS N1	N2	N3	N4	LINKED GROUP	ELEMENT SIZE INITIAL	LOW.BD	UPP.BD	MATERIAL GROUP	SIDE CONSTRAINT CODE*	
TRUSS ELEMENTS											
1	1	2			1	20.000000	0.100000	0.100000	1	-1	0
2	2	3			2	20.000000	0.100000	0.100000	1	-1	0
3	1	4			3	20.000000	0.100000	0.100000	1	-1	0
4	4	5			4	20.000000	0.100000	0.100000	1	-1	0
5	5	6			5	20.000000	0.100000	0.100000	1	-1	0
6	2	5			6	20.000000	0.100000	0.100000	1	-1	0
7	1	5			7	20.000000	0.100000	0.100000	1	-1	0
8	2	6			8	20.000000	0.100000	0.100000	1	-1	0
9	2	4			9	20.000000	0.100000	0.100000	1	-1	0
10	3	5			10	20.000000	0.100000	0.100000	1	-1	0

* -2=FIXED AT INITIAL VALUE -1=LOWER BOUNDS ONLY
0=NON NEGATIVITY ONLY 1=UPPER BOUNDS ONLY
2=BOTH UPPER AND LOWER BOUNDS
SECOND NUMBER = DISCRETE VALUE GROUP NUMBER

MATERIAL CONSTANTS - ISOTROPIC MATERIALS

GROUP NO.	YOUNG'S MODULUS	POISSON'S RATIO	SPECIFIC WEIGHT	THERMAL EXPANSION	COMPRESSIVE A. STRESS	TENSILE A. STRESS
1	10000000.0	0.3000	0.100000	0.0	-25000.0	25000.0

LOAD CONDITIONS

LUMPED LOAD AT NODES

NODE NUMBER	X	Y	Z
LOAD CONDITION 1			
2	0.0	-100000.000	0.0
3	0.0	-100000.000	0.0

PRESSURE LOAD

NO PRESSURE LOAD SPECIFIED

GRAVITY LOAD

LOAD CONDITION NO.	MAGNITUDE(G)	DIRECTION COSINES
0	NO GRAVITY LOAD	

THERMAL LOAD

NO THERMAL LOAD SPECIFIED

CONSTRAINT DATA

SIDE CONSTRAINTS

SIDE CONSTRAINT SPECIFICATIONS ARE GIVEN IN THE ELEMENT DATA

DISPLACEMENT CONSTRAINTS

INITIAL TRUNCATION FACTOR 0.1000
MAXIMUM TRUNCATION FACTOR 0.8000
BASIS CUTOFF FACTOR 1.0000
MULTIPLIER FOR TRF UPDATING 1.2000
MINIMUM NORMALIZATION FACTOR 0.0100

	NODE NO.	DIRECTION**	CODE*	REGION NO.	LOWER BOUND	UPPER BOUND
1	4	2	2		-2.000000	-2.000000
2	5	2	2		-1.000000	-1.000000

*-1=LOWER BOUND ONLY, 0=NO CONSTRAINT
1=UPPER BOUND ONLY, 2=LOWER AND UPPER BOUNDS
** IF 0, SPHERICAL DISPLACEMENT BOUND

SLOPE/RELATIVE DISPLACEMENT CONSTRAINTS

NO SLOPE CONSTRAINTS

STRESS/STRAIN CONSTRAINTS

INITIAL TRUNCATION FACTOR 0.1000
MAXIMUM TRUNCATION FACTOR 0.8000
BASIS CUTOFF FACTOR 1.0000
MULTIPLIER FOR TRF UPDATING 1.2000
MINIMUM NORMALIZATION FACTOR
STRESS 1000.0000
STRAIN 0.100000E+00
NO EULER BUCKLING CONSTRAINTS IMPOSED
SELECTION FACTOR FOR 0.1000
ZERO ORDER APPROXIMATION

ELEMENT TYPE 1

ALL ELEMENTS ARE CONSTRAINED BY BOTH LOWER AND UPPER BOUNDS

OPTIMIZER CONTROL PARAMETERS

DUAL 2
PRINT OUT CONTROL 1
MAX. NO. OF STAGES 10
DIMINISHING RETURN CRITERION AMONG STAGES 0.1000E-03
DIMINISHING RETURN CRITERION AMONG O.D.M. 0.1000E-03
MAX. STEP SIZE ALLOWED IN A SINGLE STAGE 0.1000E+04
STEP SIZE MODIFICATION FACTOR 0.1000E+01
STEP SIZE MINIMUM ALLOWABLE 0.1200E+01

CONSTRAINT IDENTIFICATION CODES

CONSTRAINT TYPE 1 10 CONSTRAINTS IN THIS TYPE
-10001 -10002 -10003 -10004 -10005 -10006 -10007 -10008 -10009 -10010

CONSTRAINT TYPE 2 4 CONSTRAINTS IN THIS TYPE
-100120004 100120004 -100220005 100220005

CONSTRAINT TYPE 3 0 CONSTRAINTS IN THIS TYPE

CONSTRAINT TYPE 4 20 CONSTRAINTS IN THIS TYPE
-10010001 10010001 -10010002 10010002 -10010003 10010003 -10010004 10010004 -10010005 10010005
-10010006 10010006 -10010007 10010007 -10010008 10010008 -10010009 10010009 -10010010 10010010

CONSTRAINT TYPE 5 0 CONSTRAINTS IN THIS TYPE

CONSTRAINT TYPE 6 0 CONSTRAINTS IN THIS TYPE

```
CONSTRAINT IDENTIFICATION CODES

  CONSTRAINT TYPE  1              10  CONSTRAINTS IN THIS TYPE
     -10001     -10002      -10003      -10004      -10005      -10006      -10007      -10008      -10009      -10010

  CONSTRAINT TYPE  2               4  CONSTRAINTS IN THIS TYPE
    -100120004   100120004  -100220005   100220005

  CONSTRAINT TYPE  3               0  CONSTRAINTS IN THIS TYPE

  CONSTRAINT TYPE  4              20  CONSTRAINTS IN THIS TYPE
    -10010001   10010001   -10010002   10010002   -10010003   10010003   -10010004   10010004   -10010005   10010005
    -10010006   10010006   -10010007   10010007   -10010008   10010008   -10010009   10010009   -10010010   10010010

  CONSTRAINT TYPE  5               0  CONSTRAINTS IN THIS TYPE

  CONSTRAINT TYPE  6               0  CONSTRAINTS IN THIS TYPE

NUMBER OF BEHAVIOUR CONSTRAINTS   24
NUMBER OF DESIGN VARIABLES        10
NUMBER OF DISCRETE VARIABLES       0

                         END OVERLAY PREPCO

                         ENTER OVERLAY DESIGN
```

STAGE NO. 1 APPROXIMATE PROBLEM GENERATOR

CURRENT MEMBER SIZE

MEMBER TYPE NUMBER 1
0.2000E+02 0.2000E+02 0.2000E+02 0.2000E+02 0.2000E+02 0.2000E+02 0.2000E+02 0.2000E+02 0.2000E+02 0.2000E+02

CURRENT WEIGHT DATA

MEMBER TYPE NUMBER 1 WEIGHT = 0.839292E+04

VARIABLE STRUCTURAL WEIGHT 0.839292E+04
FIXED STRUCTURAL WEIGHT 0.0
TOTAL STRUCTURAL WEIGHT 0.839292E+04
NON-STRUCTURAL WEIGHTHT 0.0

TOTAL WEIGHT 0.839292E+04

CONVERGENCE CHECK STAGE NO.= 1 0.1191E+27 0.1000E+01 MUST BE LESS THAN 0.100000E-03
OBJECTIVE FUNCTION OF THREE CONSECUTIVE STAGES ARE 0.200000E+31 0.100000E+31 0.839292E+04

ENTER OVERLAY ANALYS

NODAL DISPLACEMENTS

NODE	X	Y	Z	NODE	X	Y	Z
LOAD CONDITION 1							
1	0.0	0.0	0.0	2	-0.36834E+00	-0.90105E+00	0.0
3	-0.47611E+00	-0.19698E+01	0.0	4	0.42388E+00	-0.18975E+01	0.0
5	0.35165E+00	-0.83717E+00	0.0	6	0.0	0.0	0.0

NODAL DISPLACEMENTS

NODE	X	Y	Z	NODE	X	Y	Z
LOAD CONDITION 1							
1	0.0	0.0	0.0	2	-0.36834E+00	-0.90105E+00	0.0
3	-0.47611E+00	-0.19698E+01	0.0	4	0.42388E+00	-0.18975E+01	0.0
5	0.35165E+00	-0.83717E+00	0.0	6	0.0	0.0	0.0

4 DISPLACEMENT CONSTRAINTS 1 TO 4 MOST CRITICAL CONSTRAINT= -0.1628311E+00
0.5123E-01 -0.5123E-01 0.1628E+00 -0.1628E+00

MTYP	M	LC	S-COMBINED	SX	SY	SXY	SX-THERM	SY-THERM	SXY-THERM
1	1	1	-0.102316E+05	-0.1023E+05	0.0	0.0			
1	1	1	-0.102316E+05	-0.1023E+05	0.0	0.0			
1	2	1	-0.299372E+04	-0.2994E+04	0.0	0.0			
1	2	1	-0.299372E+04	-0.2994E+04	0.0	0.0			
1	3	1	0.200619E+04	0.2006E+04	0.0	0.0			
1	3	1	0.200619E+04	0.2006E+04	0.0	0.0			
1	4	1	0.200620E+04	0.2006E+04	0.0	0.0			
1	4	1	0.200620E+04	0.2006E+04	0.0	0.0			
1	5	1	0.976816E+04	0.9768E+04	0.0	0.0			
1	5	1	0.976816E+04	0.9768E+04	0.0	0.0			
1	6	1	0.177446E+04	0.1774E+04	0.0	0.0			
1	6	1	0.177446E+04	0.1774E+04	0.0	0.0			
1	7	1	-0.674326E+04	-0.6743E+04	0.0	0.0			
1	7	1	-0.674326E+04	-0.6743E+04	0.0	0.0			
1	8	1	0.739875E+04	0.7399E+04	0.0	0.0			
1	8	1	0.739875E+04	0.7399E+04	0.0	0.0			
1	9	1	-0.283721E+04	-0.2837E+04	0.0	0.0			
1	9	1	-0.283721E+04	-0.2837E+04	0.0	0.0			
1	10	1	0.423376E+04	0.4234E+04	0.0	0.0			
1	10	1	0.423376E+04	0.4234E+04	0.0	0.0			

20 STRESS/STRAIN CONSTRAINTS 5 TO 24 MOST CRITICAL CONSTRAINT= 0.5907344E+00
0.5907E+00 0.1409E+01 0.8803E+00 0.1120E+01 0.1080E+01 0.9198E+00 0.1080E+01 0.9198E+00 0.1391E+01 0.6093E+00
0.1071E+01 0.9290E+00 0.7303E+00 0.1270E+01 0.1296E+01 0.7040E+00 0.8865E+00 0.1113E+01 0.1169E+01 0.8306E+00

4 CONSTRAINTS OUT OF 4 CUTOFF POINT= 0.883717E+00
1 2 3 4

0 CONSTRAINTS OUT OF 0 CUTOFF POINT= 0.883717E+00

10 CONSTRAINTS OUT OF 20 CUTOFF POINT= 0.959073E+00
5 7 10 12 14 16 17 20 21 24

10 CONSTRAINTS OUT OF 10 RETAINED DUE TO VARIABLE LINKING
5 7 10 12 14 16 17 20 21 24

0 CONSTRAINTS OUT OF 0 CUTOFF POINT= 0.959073E+00

0 CONSTRAINTS OUT OF 0 CUTOFF POINT= 0.959073E+00

AVAILABLE INTEGER ARRAY= 2500 OVERLAY ANALYS REQUIREMENT= 314

POSTURE TABLE

RETAINED	TOTAL	TYPE	MEMBER	NODE	DIRECTION	L.C.	MODE	CONSTRAINT VALUES
DISPLACEMENT CONSTRAINTS			MOST CRITICAL = -0.162831E+00					
1	1			2	4	1	-1	0.512276E-01
2	2			2	4	1	1	-0.512276E-01
3	3			2	5	1	-1	0.162831E+00
4	4			2	5	1	1	-0.162831E+00
STRESS/STRAIN CONSTRAINTS			MOST CRITICAL = 0.590734E+00					
5	5	1	1			1	-1	0.590734E+00
6	7	1	2			1	-1	0.880251E+00
7	10	1	3			1	1	0.919752E+00
8	12	1	4			1	1	0.919752E+00
9	14	1	5			1	1	0.609273E+00
10	16	1	6			1	1	0.929021E+00
11	17	1	7			1	-1	0.730270E+00
12	20	1	8			1	1	0.704050E+00
13	21	1	9			1	-1	0.886512E+00
14	24	1	10			1	1	0.830650E+00

MODE STANDS FOR THE FOLLOWING
NEGATIVE=LOWER BOUND POSITIVE=UPPER BOUND
FOR STRESS CONSTRAINT, (CODE+1)
1 = VON MISES EQUIVALENT STRESS
2 = LONGITUDINAL STRAIN
3 = TRANSVERSE STRAIN
4 = SHEAR STRAIN
5 = FIRST EQUATION OF STRESS INTERACTION
6 = SECOND EQUATION OF STRESS INTERACTION
7 = TSAI-AZZI CRITERION
FOR FREQUENCY CONSTRAINTS, ASSOCIATED MODE NUMBER

AVAILABLE REAL ARRAY = 7500 OVERLAY ANALYS REQUIREMENT= 304

SELECTION OF 10 1ST ORDER APPROXIMATED STRESS CONSTRAINTS NEW NUMBER OF LINEARIZED CONSTRAINTS - NTCE = 14

ANALYSIS TIME DATA	
ASSEMBLE MASS/STIFFNESS MATRIX	0.279083E-01
ASSEMBLE LOAD VECTORS	0.320435E-03
DECOMPOSE STIFFNESS MATRIX	0.732422E-03
SOLUTION OF DISPLACEMENTS	0.732422E-03
FREQUENCY ANALYSIS	0.0
FLUTTER ANALYSIS	0.106812E-03
CONSTRAINT EVALUATION	0.335388E-01
POSTURE TABLE SET	0.304108E-01
SELECTIVE GRADIENT EVALUATION	0.165833E+00
GRAND TOTAL CPU TIME	0.286255E+00

END OVERLAY ANALYS

SCALING FACTOR 0.116283E+01 SCALED WEIGHT 0.975954E+04

NEW LIST OF LINEARIZED CONSTRAINTS

1 2 3 4 5 7 10 12 14 16 17 20 21 24

SIDE CONSTRAINTS

RELATIVE MOVE LIMIT 0.1000E-02

VARIABLE NUMBER	LOWER BOUND	ACTUAL SIZE	UPPER BOUND	VARIABLE NUMBER	LOWER BOUND	ACTUAL SIZE	UPPER BOUND
1	0.1000E+00	0.2000E+02	0.2000E+05	2	0.1000E+00	0.2000E+02	0.2000E+05
3	0.1000E+00	0.2000E+02	0.2000E+05	4	0.1000E+00	0.2000E+02	0.2000E+05
5	0.1000E+00	0.2000E+02	0.2000E+05	6	0.1000E+00	0.2000E+02	0.2000E+05
7	0.1000E+00	0.2000E+02	0.2000E+05	8	0.1000E+00	0.2000E+02	0.2000E+05
9	0.1000E+00	0.2000E+02	0.2000E+05	10	0.1000E+00	0.2000E+02	0.2000E+05

MOST VIOLATED SIDE CONSTRAINT - DESIGN VARIABLE 10 CONSTRAINT VALUE 0.9950E+00

NEW LIST OF LINEARIZED CONSTRAINTS

1 2 3 4 5 7 10 12 14 16 17 20 21 24

SIDE CONSTRAINTS

RELATIVE MOVE LIMIT 0.1000E-02

VARIABLE NUMBER	LOWER BOUND	ACTUAL SIZE	UPPER BOUND	VARIABLE NUMBER	LOWER BOUND	ACTUAL SIZE	UPPER BOUND
1	0.1000E+00	0.2000E+02	0.2000E+05	2	0.1000E+00	0.2000E+02	0.2000E+05
3	0.1000E+00	0.2000E+02	0.2000E+05	4	0.1000E+00	0.2000E+02	0.2000E+05
5	0.1000E+00	0.2000E+02	0.2000E+05	6	0.1000E+00	0.2000E+02	0.2000E+05
7	0.1000E+00	0.2000E+02	0.2000E+05	8	0.1000E+00	0.2000E+02	0.2000E+05
9	0.1000E+00	0.2000E+02	0.2000E+05	10	0.1000E+00	0.2000E+02	0.2000E+05

MOST VIOLATED SIDE CONSTRAINT - DESIGN VARIABLE 10 CONSTRAINT VALUE 0.9950E+00

ENTER OVERLAY PREDU2

AVAILABLE REAL ARRAY = 7500 OVERLAY PREDU2 REQUIREMENT= 389
AVAILABLE INTEGER ARRAY= 2500 OVERLAY PREDU2 REQUIREMENT= 327

```
=====   MAXIMIZATION OF DUAL FUNCTION BY NEWTON METHOD   =====

STARTING POINT
        CONSTRAINT    1     DUAL VARIABLE =    0.318613E+03
ITERATION   1
 NORM OF PROJECTED GRADIENT                    0.816564E-05
 LIST OF ACTIVE CONSTRAINTS                    1     7
ITERATION   2
 NORM OF PROJECTED GRADIENT                    0.130177E+02
 LIST OF ACTIVE CONSTRAINTS                    1     7
ITERATION   3
 NORM OF PROJECTED GRADIENT                    0.310776E+01
 LIST OF ACTIVE CONSTRAINTS                    1     7
ITERATION   4
 NORM OF PROJECTED GRADIENT                    0.404002E+01
 LIST OF ACTIVE CONSTRAINTS                    1     7
ITERATION   5
 NORM OF PROJECTED GRADIENT                    0.189293E+01
 LIST OF ACTIVE CONSTRAINTS                    1     7
ITERATION   6
 NORM OF PROJECTED GRADIENT                    0.733978E+00
 LIST OF ACTIVE CONSTRAINTS                    1     7
ITERATION   7
 NORM OF PROJECTED GRADIENT                    0.190092E+00
 LIST OF ACTIVE CONSTRAINTS                    1     7
ITERATION   8
 NORM OF PROJECTED GRADIENT                    0.194896E-01
 LIST OF ACTIVE CONSTRAINTS                    1     7
ITERATION   9
 NORM OF PROJECTED GRADIENT                    0.285972E-03
 LIST OF ACTIVE CONSTRAINTS                    1     7
ITERATION  10
 NORM OF PROJECTED GRADIENT                    0.192597E-04
 LIST OF ACTIVE CONSTRAINTS                    1     7    10
ITERATION  11
 NORM OF PROJECTED GRADIENT                    0.119668E+01
 LIST OF ACTIVE CONSTRAINTS                    1     7    10
```

NORM OF PROJECTED GRADIENT	0.733978E+00
LIST OF ACTIVE CONSTRAINTS	1 7

ITERATION 7

NORM OF PROJECTED GRADIENT	0.190092E+00
LIST OF ACTIVE CONSTRAINTS	1 7

ITERATION 8

NORM OF PROJECTED GRADIENT	0.194896E-01
LIST OF ACTIVE CONSTRAINTS	1 7

ITERATION 9

NORM OF PROJECTED GRADIENT	0.285972E-03
LIST OF ACTIVE CONSTRAINTS	1 7

ITERATION 10

NORM OF PROJECTED GRADIENT	0.192597E-04
LIST OF ACTIVE CONSTRAINTS	1 7 10

ITERATION 11

NORM OF PROJECTED GRADIENT	0.119668E+01
LIST OF ACTIVE CONSTRAINTS	1 7 10

ITERATION 12

NORM OF PROJECTED GRADIENT	0.508975E+00
LIST OF ACTIVE CONSTRAINTS	1 7 10

ITERATION 13

NORM OF PROJECTED GRADIENT	0.159497E+00
LIST OF ACTIVE CONSTRAINTS	1 7 10

ITERATION 14

NORM OF PROJECTED GRADIENT	0.244894E-01
LIST OF ACTIVE CONSTRAINTS	1 7 10

ITERATION 15

NORM OF PROJECTED GRADIENT	0.746817E-03
LIST OF ACTIVE CONSTRAINTS	1 7 10

ITERATION 16

NORM OF PROJECTED GRADIENT	0.202480E-05
LIST OF ACTIVE CONSTRAINTS	1 7 10 4

ITERATION 17

NORM OF PROJECTED GRADIENT	0.388537E+00
LIST OF ACTIVE CONSTRAINTS	1 7 4

ITERATION 18

NORM OF PROJECTED GRADIENT	0.199019E+00
LIST OF ACTIVE CONSTRAINTS	1 7 4

ITERATION 19

NORM OF PROJECTED GRADIENT 0.755865E-01

LIST OF ACTIVE CONSTRAINTS 1 7 4

ITERATION 20

NORM OF PROJECTED GRADIENT 0.121933E-01

LIST OF ACTIVE CONSTRAINTS 1 7 4

ITERATION 21

NORM OF PROJECTED GRADIENT 0.330171E-03

LIST OF ACTIVE CONSTRAINTS 1 7 4

ITERATION NUMBER 22

PRIMAL VARIABLES EVALUATIONS 47

NORM OF DUAL FUNCTION GRADIENT 0.250481E-05

DUAL OBJECTIVE FUNCTION 473.837109E+01

FINAL WEIGHT 473.836719E+01

LIST OF ACTIVE CONSTRAINTS 1 7 4

LINEARIZED CONSTRAINTS

CONSTRAINT NO	CURRENT VALUE	LIMITING VALUE LOWER	LIMITING VALUE UPPER	DUAL VARIABLE
1	0.999993E+00	-0.999992E+30	0.999992E+00	0.434644E+04
2	-0.999993E+00	-0.999992E+30	-0.999992E+00	0.0
3	0.999991E+00	-0.999993E+30	0.999993E+00	0.0
4	-0.999991E+00	-0.999993E+30	-0.999993E+00	0.665807E+03
5	0.368678E+00	-0.999996E+30	0.999996E+00	0.0
6	0.441806E+00	-0.999998E+30	0.999998E+00	0.0
7	0.999997E+00	-0.999999E+30	0.999999E+00	0.105776E+04
8	0.974624E-01	-0.999998E+30	0.999998E+00	0.0
9	0.292556E+00	-0.999997E+30	0.999997E+00	0.0
10	0.281930E+00	-0.999999E+30	0.999999E+00	0.0
11	0.409273E+00	-0.999997E+30	0.999997E+00	0.0
12	0.512176E+00	-0.999997E+30	0.999997E+00	0.0
13	0.352379E-01	-0.999999E+30	0.999999E+00	0.0
14	0.504031E+00	-0.999999E+30	0.999999E+00	0.0

END OVERLAY PREDL2

```
RESFONSE FACTOR REDUCED TO    0.C

TRUNCATION FACTORS MODIFIED AS FOLLOWS
    DISPLACEMENT CONSTRAINTS      0.120000E+00
    STRESS/STRAIN CONSTRAINT      0.120000E+00
    SELECTION FACTOR (F.S.D.)     0.100000E+00

    UPDATED SCALING FACTORS
        0.1231E+01  0.4107E+00  0.6977E-01  0.3240E+00  0.1189E+01  0.1516E+00  0.5859E+00  0.6419E+00  0.4582E+00  0.5808E+00

    UPDATED WEIGHT COEFFICIENTS
        0.8861E+03  0.2957E+03  0.5023E+02  0.2333E+03  0.8559E+03  0.1091E+03  0.5966E+03  0.6536E+03  0.4665E+03  0.5914E+03
        0.0         0.0
```

STAGE NO. 2 APPROXIMATE PROBLEM GENERATOR

CURRENT MEMBER SIZE

MEMBER TYPE NUMBER 1
0.2461E+02 0.8214E+01 0.1395E+01 0.6480E+01 0.2377E+02 0.3031E+01 0.1172E+02 0.1284E+02 0.9164E+01 0.1162E+02

CURRENT WEIGHT DATA

MEMBER TYPE NUMBER 1 WEIGHT = 0.473837E+04

VARIABLE STRUCTURAL WEIGHT 0.473837E+04
FIXED STRUCTURAL WEIGHT 0.0
TOTAL STRUCTURAL WEIGHT 0.473837E+04
NON-STRUCTURAL WEIGHTHT 0.0

TOTAL WEIGHT 0.473837E+04

CONVERGENCE CHECK STAGE NO.= 2 0.7713E+00 0.1191E+27 MUST BE LESS THAN 0.100000E-03
OBJECTIVE FUNCTION OF THREE CONSECUTIVE STAGES ARE 0.100000E+31 0.839292E+04 0.473837E+04

ENTER OVERLAY ANALYS

AVAILABLE INTEGER ARRAY= 2500 OVERLAY ANALYS REQUIREMENT= 314

POSTURE TABLE

RETAINED	TOTAL	TYPE	MEMBER	NODE	DIRECTION	L.C.	MODE	CONSTRAINT VALUES
DISPLACEMENT CONSTRAINTS		MOST CRITICAL =		-0.691996E-01				
1	1			2	4	1	-1	-0.691996E-01
2	2			2	4	1	1	0.691996E-01
3	3			2	5	1	-1	-0.615721E-01
4	4			2	5	1	1	0.615721E-01
STRESS/STRAIN CONSTRAINTS		MOST CRITICAL =		0.387008E+00				
5	5	1	1			1	-1	0.657426E+00
6	7	1	2			1	-1	0.617142E+00
7	10	1	3			1	1	0.387008E+00
8	12	1	4			1	1	0.867999E+00
9	14	1	5			1	1	0.681680E+00
10	16	1	6			1	1	0.860421E+00
11	17	1	7			1	-1	0.569398E+00
12	20	1	8			1	1	0.511736E+00
13	21	1	9			1	-1	0.867999E+00
14	24	1	10			1	1	0.617144E+00

MODE STANDS FOR THE FOLLOWING
NEGATIVE=LOWER BOUND POSITIVE=UPPER BOUND
FOR STRESS CONSTRAINT. (CODE+1)
1 = VON MISES EQUIVALENT STRESS
2 = LONGITUDINAL STRAIN

NEGATIVE=LOWER BOUND   POSITIVE=UPPER BOUND
FOR STRESS CONSTRAINT. (CODE+1)
1 = VON MISES EQUIVALENT STRESS
2 = LONGITUDINAL STRAIN
3 = TRANSVERSE STRAIN
4 = SHEAR STRAIN
5 = FIRST EQUATION OF STRESS INTERACTION
6 = SECOND EQUATION OF STRESS INTERACTION
7 = TSAI-AZZI CRITERION
FOR FREQUENCY CONSTRAINTS, ASSOCIATED MODE NUMBER

AVAILABLE REAL ARRAY = 7500   OVERLAY ANALYS REQUIREMENT= 304

END OVERLAY ANALYS

SCALING FACTOR 0.106920E+01   SCALED WEIGHT 0.506626E+04

NEW LIST OF LINEARIZED CONSTRAINTS

1 2 3 4 10 16 17 20 21 24

SIDE CONSTRAINTS

RELATIVE MOVE LIMIT 0.1000E-02

VARIABLE NUMBER	LOWER BOUND	ACTUAL SIZE	UPPER BOUND	VARIABLE NUMBER	LOWER BOUND	ACTUAL SIZE	UPPER BOUND
1	0.8432E+01	0.2461E+02	0.2461E+05	2	0.3145E+01	0.8214E+01	0.8214E+04
3	0.1000E+00	0.1395E+01	0.1395E+04	4	0.8553E+00	0.6480E+01	0.6480E+04
5	0.7568E+01	0.2377E+02	0.2377E+05	6	0.1000E+00	0.3031E+01	0.3031E+04
7	0.1000E+00	0.1172E+02	0.1172E+05	8	0.1000E+00	0.1284E+02	0.1284E+05
9	0.1000E+00	0.9164E+01	0.9164E+04	10	0.1000E+00	0.1162E+02	0.1162E+05

MOST VIOLATED SIDE CONSTRAINT - DESIGN VARIABLE 2   CONSTRAINT VALUE 0.6171E+00

ENTER OVERLAY PREDU2

AVAILABLE REAL ARRAY = 7500   OVERLAY PREDU2 REQUIREMENT= 275
AVAILABLE INTEGER ARRAY= 2500   OVERLAY PREDU2 REQUIREMENT= 323

===== MAXIMIZATION OF DUAL FUNCTION BY NEWTON METHOD =====

ITERATION 1

NORM OF PROJECTED GRADIENT   0.426830E+01

LIST OF ACTIVE CONSTRAINTS   1 4 5

ITERATION 2

===== MAXIMIZATION OF DUAL FUNCTION BY NEWTON METHOD =====

ITERATION 1

NORM OF PROJECTED GRADIENT 0.426830E+01

LIST OF ACTIVE CONSTRAINTS 1 4 5

ITERATION 2

NORM OF PROJECTED GRADIENT 0.425099E+01

LIST OF ACTIVE CONSTRAINTS 1 4 5

ITERATION 3

NORM OF PROJECTED GRADIENT 0.396776E+00

LIST OF ACTIVE CONSTRAINTS 1 4 5

ITERATION 4

NORM OF PROJECTED GRADIENT 0.181875E+00

LIST OF ACTIVE CONSTRAINTS 1 4 5

ITERATION 5

NORM OF PROJECTED GRADIENT 0.135036E-01

LIST OF ACTIVE CONSTRAINTS 1 4 5

ITERATION 6

NORM OF PROJECTED GRADIENT 0.667348E-03

LIST OF ACTIVE CONSTRAINTS 1 4 5

ITERATION NUMBER 7

PRIMAL VARIABLES EVALUATIONS 26

NORM OF DUAL FUNCTION GRADIENT 0.638549E-05

DUAL OBJECTIVE FUNCTION 439.013672E+01

FINAL WEIGHT 439.014062E+01

LIST OF ACTIVE CONSTRAINTS 1 4 5

LINEARIZED CONSTRAINTS

CONSTRAINT NO	CURRENT VALUE	LIMITING VALUE LOWER	LIMITING VALUE UPPER	DUAL VARIABLE
1	0.999996E+00	-0.999998E+30	0.999998E+00	0.381796E+04
2	-0.999996E+00	-0.999998E+30	-0.999998E+00	0.0
3	0.999996E+00	-0.999998E+30	0.999998E+00	0.0
4	-0.999996E+00	-0.999998E+30	-0.999998E+00	0.415256E+03
5	0.100001E+01	-0.100000E+31	0.100000E+01	0.987451E+03
6	0.309419E+00	-0.999998E+30	0.999998E+00	0.0
7	0.395159E+00	-0.999999E+30	0.999999E+00	0.0
8	0.524055E+00	-0.999998E+30	0.999998E+00	0.0
9	0.361614E-01	-0.100000E+31	0.100000E+01	0.0

LINEARIZED CONSTRAINTS

CONSTRAINT NO	CURRENT VALUE	LIMITING VALUE LOWER	LIMITING VALUE UPPER	DUAL VARIABLE
1	0.999996E+00	-0.999998E+30	0.999998E+00	0.381796E+04
2	-0.999996E+00	-0.999998E+30	-0.999998E+00	0.0
3	0.999996E+00	-0.999998E+30	0.999998E+00	0.0
4	-0.999996E+00	-0.999998E+30	-0.999998E+00	0.415256E+03
5	0.100001E+01	-0.100000E+31	0.100000E+01	0.987451E+03
6	0.309419E+00	-0.999998E+30	0.999998E+00	0.0
7	0.395159E+00	-0.999999E+30	0.999999E+00	0.0
8	0.524055E+00	-0.999998E+30	0.999998E+00	0.0
9	0.361614E-01	-0.100000E+31	0.100000E+01	0.0
10	0.472636E+00	-0.100000E+31	0.100000E+01	0.0

END OVERLAY PREDU2

RESPONSE FACTOR REDUCED TO C.0

TRUNCATICN FACTORS MODIFIED AS FOLLOWS

DISPLACEMENT CONSTRAINTS	0.358317E+00
STRESS/STRAIN CCNSTRAINT	0.358317E+00
SELECTION FACTOR (F.S.D.)	0.100000E+00

UPDATED SCALING FACTORS

0.1079E+01	0.4217E+00	0.5000E-02	0.7006E-01	0.1133E+01	0.5000E-C2	0.7272E+00	0.6347E+00	0.9908E-01	0.5964E+00

UPDATED WEIGHT COEFFICIENTS

0.7768E+03	0.3036E+03	0.3600E+01	0.5044E+C2	0.8159E+03	0.3600E+01	0.7405E+03	0.6463E+03	0.1009E+03	0.6072E+03
0.0	0.0								

```
STAGE NO. 8   APPRCXIMATE PROBLEM GENERATOR

CURRENT MEMBER SIZE
  MEMBER TYPE NUMBER  1
     0.2158E+02  0.8434E+01  0.1000E+00  0.1401E+01  0.2266E+02  0.100CE+00  0.1454E+02  0.1269E+02  0.1982E+01  0.1193E+02

CURRENT WEIGHT DATA
  MEMBER TYPE NUMBER    1      WEIGHT =   0.404881E+04

      VARIABLE STRUCTURAL WEIGHT   0.404881E+04
      FIXED STRUCTURAL WEIGHT      0.0
          TOTAL STRUCTURAL WEIGHT      0.404881E+04
          NCN-STRUCTURAL WEIGHTHT      0.0

              TOTAL WEIGHT                 0.404881E+04

  CONVERGENCE CHECK     STAGE NO.=    8         0.5246E-04      0.9922E-03   MUST BE LESS THAN   0.100000E-03
     OBJECTIVE FUNCTION OF THREE CONSECUTIVE STAGES ARE   0.404501E+04   0.404903E+04   0.404881E+04

                                   ENTER OVERLAY ANALYS

AVAILABLE INTEGER ARRAY=   2500   OVERLAY ANALYS REQUIREMENT=    310

                                   POSTURE TABLE

     RETAINED     TOTAL      TYPE    MEMBER      NODE DIRECTION      L.C.       MODE   CONSTRAINT VALUES

     DISPLACEMENT CONSTRAINTS     MOST CRITICAL =  -0.371933E-04
           1          1                            2       4          1          -1       -0.371933E-04
           2          2                            2       4          1           1        0.371933E-04
           3          3                            2       5          1          -1       -0.209808E-04
           4          4                            2       5          1           1        0.209808E-04

     STRESS/STRAIN CONSTRAINTS     MOST CRITICAL =  -0.376562E-04
           5          5        1         1                            1          -1        0.625415E+00
           6          7        1         2                            1          -1        0.537578E+00
           7         10        1         3                            1           1       -0.376562E-04
           8         17        1         7                            1          -1        0.619110E+00
           9         20        1         8                            1           1        0.545171E+00
          10         24        1        10                            1           1        0.537578E+00

        MODE STANDS FOR THE FOLLOWING
           NEGATIVE=LOWER BOUND    POSITIVE=UPPER BOUND
            FOR STRESS CONSTRAINT, (CODE+1)
               1 = VON MISES EQUIVALENT STRESS
               2 = LONGITUDINAL STRAIN
               3 = TRANSVERSE STRAIN
               4 = SHEAR STRAIN
               5 = FIRST EQUATION OF STRESS INTERACTION
               6 = SECOND EQUATION OF STRESS INTERACTION
               7 = TSAI-AZZI CRITERION
               FOR FREQUENCY CONSTRAINTS, ASSOCIATED MODE NUMBER

AVAILABLE REAL ARRAY   =   7500   OVERLAY ANALYS REQUIREMENT=    300

                                   END OVERLAY ANALYS

        SCALING FACTOR      0.100004E+01          SCALED WEIGHT       0.404896E+04

NEW LIST OF LINEARIZED CONSTRAINTS
   1    2    3    4   10

                                   SIDE CONSTRAINTS
```

```
3 = TRANSVERSE STRAIN
4 = SHEAR STRAIN
5 = FIRST EQUATION OF STRESS INTERACTION
6 = SECOND EQUATION OF STRESS INTERACTION
7 = TSAI-AZZI CRITERION
FOR FREQUENCY CONSTRAINTS, ASSOCIATED MODE NUMBER
```

```
----------------------------------------------------------------------------
AVAILABLE REAL ARRAY    =    7500    OVERLAY ANALYS REQUIREMENT=     300
----------------------------------------------------------------------------
```

END OVERLAY ANALYS

SCALING FACTOR   0.100004E+01   SCALED WEIGHT   0.404896E+04

NEW LIST OF LINEARIZED CONSTRAINTS

1 2 3 4 10

SIDE CONSTRAINTS

RELATIVE MOVE LIMIT   0.1000E-02

VARIABLE NUMBER	LOWER BOUND	ACTUAL SIZE	UPPER BOUND	VARIABLE NUMBER	LOWER BOUND	ACTUAL SIZE	UPPER BOUND
1	0.8083E+01	0.2158E+02	0.2158E+05	2	0.3900E+01	0.8434E+01	0.8434E+04
3	0.1000E+00	0.1000E+00	0.1000E+03	4	0.1000E+00	0.1401E+01	0.1401E+04
5	0.1000E+00	0.2266E+02	0.2266E+05	6	0.1000E+00	0.1000E+00	0.1000E+03
7	0.5540E+01	0.1454E+02	0.1454E+05	8	0.5774E+01	0.1269E+02	0.1269E+05
9	0.1000E+00	0.1982E+01	0.1982E+04	10	0.5515E+01	0.1193E+02	0.1193E+05

MOST VIOLATED SIDE CONSTRAINT - DESIGN VARIABLE 6   CONSTRAINT VALUE 0.0

ENTER OVERLAY PREDU2

```
----------------------------------------------------------------------------
AVAILABLE REAL ARRAY    =    7500    OVERLAY PREDU2 REQUIREMENT=     155
AVAILABLE INTEGER ARRAY=     2500    OVERLAY PREDU2 REQUIREMENT=     314
----------------------------------------------------------------------------
```

===== MAXIMIZATION OF DUAL FUNCTION BY NEWTON METHOD =====

ITERATION 1

NORM OF PROJECTED GRADIENT	0.567979E-03
LIST OF ACTIVE CONSTRAINTS	1 3 5
ITERATION NUMBER	2
PRIMAL VARIABLES EVALUATIONS	2
NORM OF DUAL FUNCTION GRADIENT	0.955535E-06
DUAL OBJECTIVE FUNCTION	404.895508E+01
FINAL WEIGHT	404.895557E+01
LIST OF ACTIVE CONSTRAINTS	1 3 5

LINEARIZED CONSTRAINTS

CONSTRAINT NO	CURRENT VALUE	LIMITING VALUE LOWER	LIMITING VALUE UPPER	DUAL VARIABLE
1	0.999997E+00	-0.999997E+30	0.999997E+00	0.302979E+04
2	-0.999997E+00	-0.999997E+30	-0.999997E+00	0.0
3	0.999998E+00	-0.999998E+30	0.999998E+00	0.354674E+03
4	-0.999998E+00	-0.999998E+30	-0.999998E+00	0.0
5	0.100000E+01	-0.100000E+31	0.100000E+01	0.532447E+03

END OVERLAY PREDL2

RESPONSE FACTOR REDUCED TO 0.0

TRUNCATION FACTORS MODIFIED AS FOLLOWS
DISPLACEMENT CONSTRAINTS 0.429980E+00
STRESS/STRAIN CONSTRAINT 0.429980E+00
SELECTION FACTOR (F.S.D.) 0.100000E+00

UPDATED SCALING FACTORS
0.1079E+01 0.4217E+00 0.5000E-02 0.7006E-01 0.1133E+01 0.5000E-02 0.7272E+00 0.6347E+00 0.9908E-01 0.5964E+00

UPDATED WEIGHT COEFFICIENTS
0.7768E+03 0.3036E+03 0.3600E+01 0.5044E+02 0.8159E+03 0.3600E+01 0.7405E+03 0.6463E+03 0.1009E+03 0.6073E+03
0.0 0.0

RESPONSE FACTOR REDUCED TO 0.0

TRUNCATION FACTORS MODIFIED AS FOLLOWS
DISPLACEMENT CONSTRAINTS 0.429980E+00
STRESS/STRAIN CONSTRAINT 0.429980E+00
SELECTION FACTOR (F.S.D.) 0.100000E+00

UPDATED SCALING FACTORS
0.1079E+01 0.4217E+00 0.5000E-02 0.7006E-01 0.1133E+01 0.5000E-02 0.7272E+00 0.6347E+00 0.9908E-01 0.5964E+00

UPDATED WEIGHT COEFFICIENTS
0.7768E+03 0.3036E+03 0.3600E+01 0.5044E+02 0.8159E+03 0.3600E+01 0.7405E+03 0.6463E+03 0.1009E+03 0.6073E+03
0.0 0.0

STAGE NO. 9 APPROXIMATE PROBLEM GENERATOR

CURRENT MEMBER SIZE

MEMBER TYPE NUMBER 1
0.2158E+02 0.8434E+01 0.1000E+00 0.1401E+01 0.2266E+02 0.1000E+00 0.1454E+02 0.1269E+02 0.1982E+01 0.1193E+02

CURRENT WEIGHT DATA

MEMBER TYPE NUMBER 1 WEIGHT = 0.404896E+04

VARIABLE STRUCTURAL WEIGHT 0.404896E+04
FIXED STRUCTURAL WEIGHT 0.0
TOTAL STRUCTURAL WEIGHT 0.404896E+04
NON-STRUCTURAL WEIGHTHT 0.0

TOTAL WEIGHT 0.404896E+04

CONVERGENCE CHECK STAGE NO.= 9 0.3497E-04 0.5246E-04 MUST BE LESS THAN 0.100000E-03
OBJECTIVE FUNCTION OF THREE CONSECUTIVE STAGES ARE 0.404903E+04 0.404881E+04 0.404896E+04

ENTER OVERLAY ANALYS

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NODAL DISPLACEMENTS

NODE	X	Y	Z	NODE	X	Y	Z
LOAD CONDITION 1							
1	0.0	0.0	0.0	2	-0.33711E+00	-0.11558E+01	0.0
3	-0.75327E+00	-0.29000E+01	0.0	4	0.37864E+00	-0.20000E+01	0.0
5	0.31441E+00	-0.10000E+01	0.0	6	0.0	0.0	0.0

4 DISPLACEMENT CONSTRAINTS 1 TO 4 MOST CRITICAL CONSTRAINT= -0.1430511E-05

NODAL DISPLACEMENTS

NODE	X	Y	Z	NODE	X	Y	Z
LOAD CONDITION 1							
1	0.0	0.0	0.0	2	-0.33711E+00	-0.11558E+01	0.0
3	-0.75327E+00	-0.29000E+01	0.0	4	0.37864E+00	-0.20000E+01	0.0
5	0.31441E+00	-0.10000E+01	0.0	6	0.0	0.0	0.0

4 DISPLACEMENT CONSTRAINTS 1 TO 4 MOST CRITICAL CONSTRAINT= -0.1430511E-05
0.1431E-05 -0.1431E-05 0.1132E-05 -0.1132E-05

MTYP	M	LC	S-COMBINED	SX	SY	SXY	SX-THERM	SY-THERM	SXY-THERM
1	1	1	-0.936425E+04	-0.9364E+04	0.0	0.0			
1	1	1	-0.936425E+04	-0.9364E+04	0.0	0.0			
1	2	1	-0.115600E+05	-0.1156E+05	0.0	0.0			
1	2	1	-0.115600E+05	-0.1156E+05	0.0	0.0			
1	3	1	0.250000E+05	0.2500E+05	0.0	0.0			
1	3	1	0.250000E+05	0.2500E+05	0.0	0.0			
1	4	1	0.178421E+04	0.1784E+04	0.0	0.0			
1	4	1	0.178421E+04	0.1784E+04	0.0	0.0			
1	5	1	0.873355E+04	0.8734E+04	0.0	0.0			
1	5	1	0.873355E+04	0.8734E+04	0.0	0.0			
1	6	1	0.432727E+04	0.4327E+04	0.0	0.0			
1	6	1	0.432727E+04	0.4327E+04	0.0	0.0			
1	7	1	-0.952209E+04	-0.9522E+04	0.0	0.0			
1	7	1	-0.952209E+04	-0.9522E+04	0.0	0.0			
1	8	1	0.113704E+05	0.1137E+05	0.0	0.0			
1	8	1	0.113704E+05	0.1137E+05	0.0	0.0			
1	9	1	-0.178422E+04	-0.1784E+04	0.0	0.0			
1	9	1	-0.178422E+04	-0.1784E+04	0.0	0.0			
1	10	1	0.115600E+05	0.1156E+05	0.0	0.0			
1	10	1	0.115600E+05	0.1156E+05	0.0	0.0			

20 STRESS/STRAIN CONSTRAINTS 5 TO 24 MOST CRITICAL CONSTRAINT= -0.4687500E-06
0.6254E+00 0.1375E+01 0.5376E+00 0.1462E+01 0.2000E+01 -0.4687E-06 0.1071E+01 0.9286E+00 0.1349E+01 0.6507E+00
0.1173E+01 0.8269E+00 0.6191E+00 0.1381E+01 0.1455E+01 0.5452E+00 0.9286E+00 0.1071E+01 0.1462E+01 0.5376E+00

4 CONSTRAINTS OUT OF 4 CUTOFF POINT= 0.570020E+00
1 2 3 4

0 CONSTRAINTS OUT OF 0 CUTOFF POINT= 0.570020E+00

4 CONSTRAINTS OUT OF 20 CUTOFF POINT= 0.570020E+00
7 10 20 24

4 CONSTRAINTS OUT OF 4 RETAINED DUE TO VARIABLE LINKING
7 10 20 24

0 CONSTRAINTS OUT OF 0 CUTOFF POINT= 0.570020E+00

0 CONSTRAINTS OUT OF 0 CUTOFF POINT= 0.570020E+00

AVAILABLE INTEGER ARRAY= 2500 OVERLAY ANALYS REQUIREMENT= 308

POSTURE TABLE

RETAINED	TOTAL	TYPE	MEMBER	NODE	DIRECTION	L.C.	MODE	CONSTRAINT VALUES
DISPLACEMENT CONSTRAINTS			MOST CRITICAL =	-0.143051E-05				
1	1			2	4	1	-1	0.143051E-05
2	2			2	4	1	1	-0.143051E-05
3	3			2	5	1	-1	0.113249E-05
4	4			2	5	1	1	-0.113249E-05
STRESS/STRAIN CONSTRAINTS			MOST CRITICAL =	-0.468750E-06				
5	7	1	2			1	-1	0.537601E+00
6	10	1	3			1	1	-0.468750E-06
7	20	1	8			1	1	0.545185E+00
8	24	1	10			1	1	0.537601E+00

MODE STANDS FOR THE FOLLOWING
NEGATIVE=LOWER BOUND POSITIVE=UPPER BOUND
FOR STRESS CONSTRAINT. (CODE+1)
1 = VON MISES EQUIVALENT STRESS
2 = LONGITUDINAL STRAIN
3 = TRANSVERSE STRAIN
4 = SHEAR STRAIN
5 = FIRST EQUATION OF STRESS INTERACTION
6 = SECOND EQUATION OF STRESS INTERACTION
7 = TSAI-AZZI CRITERION
FOR FREQUENCY CONSTRAINTS. ASSOCIATED MODE NUMBER

AVAILABLE REAL ARRAY = 7500 OVERLAY ANALYS REQUIREMENT= 298

SELECTION OF 1 1ST ORDER APPROXIMATED STRESS CONSTRAINTS NEW NUMBER OF LINEARIZED CONSTRAINTS - NTCE = 5

ANALYSIS TIME DATA	
ASSEMBLE MASS/STIFFNESS MATRIX	0.235825E+00
ASSEMBLE LOAD VECTORS	0.411987E-03
DECOMPOSE STIFFNESS MATRIX	0.839233E-03
SOLUTION OF DISPLACEMENTS	0.839233E-03
FREQUENCY ANALYSIS	0.0
FLUTTER ANALYSIS	0.106812E-03
CONSTRAINT EVALUATION	0.337372E-01
POSTURE TABLE SET	0.222015E-01
SELECTIVE GRADIENT EVALUATION	0.193954E+00
GRAND TOTAL CPU TIME	0.314072E+00

END OVERLAY ANALYS

DIMINISHING RETURN OF THREE CONSECUTIVE STAGES

DESIGN TIME STATISTICS	
TOTAL	4.1873
INITIAL PREPARATION	0.0397
DESIGN PHASE	4.1477
ANALYSIS TOTAL	2.5315
OPTIMIZER TOTAL	0.2755

END OVERLAY DESIGN

MAIN PROGRAM TIME STATISTICS	
PRE-PROCESSOR	0.2518
DESIGN PHASE	4.1915

```
DESIGN TIME STATISTICS
 TOTAL                                4.1873
     INITIAL PREPARATION               0.0397
     DESIGN PHASE                      4.1477
         ANALYSIS TOTAL                   2.5315
         OPTIMIZER TOTAL                  0.2755
```

END OVERLAY DESIGN

```
MAIN PROGRAM TIME STATISTICS
  PRE-PROCESSOR                           0.2518
  DESIGN PHASE                            4.1915
  ----------------------------------------------
     GRAND TOTAL                             4.4432
```

ENTER OVERLAY PREPCO

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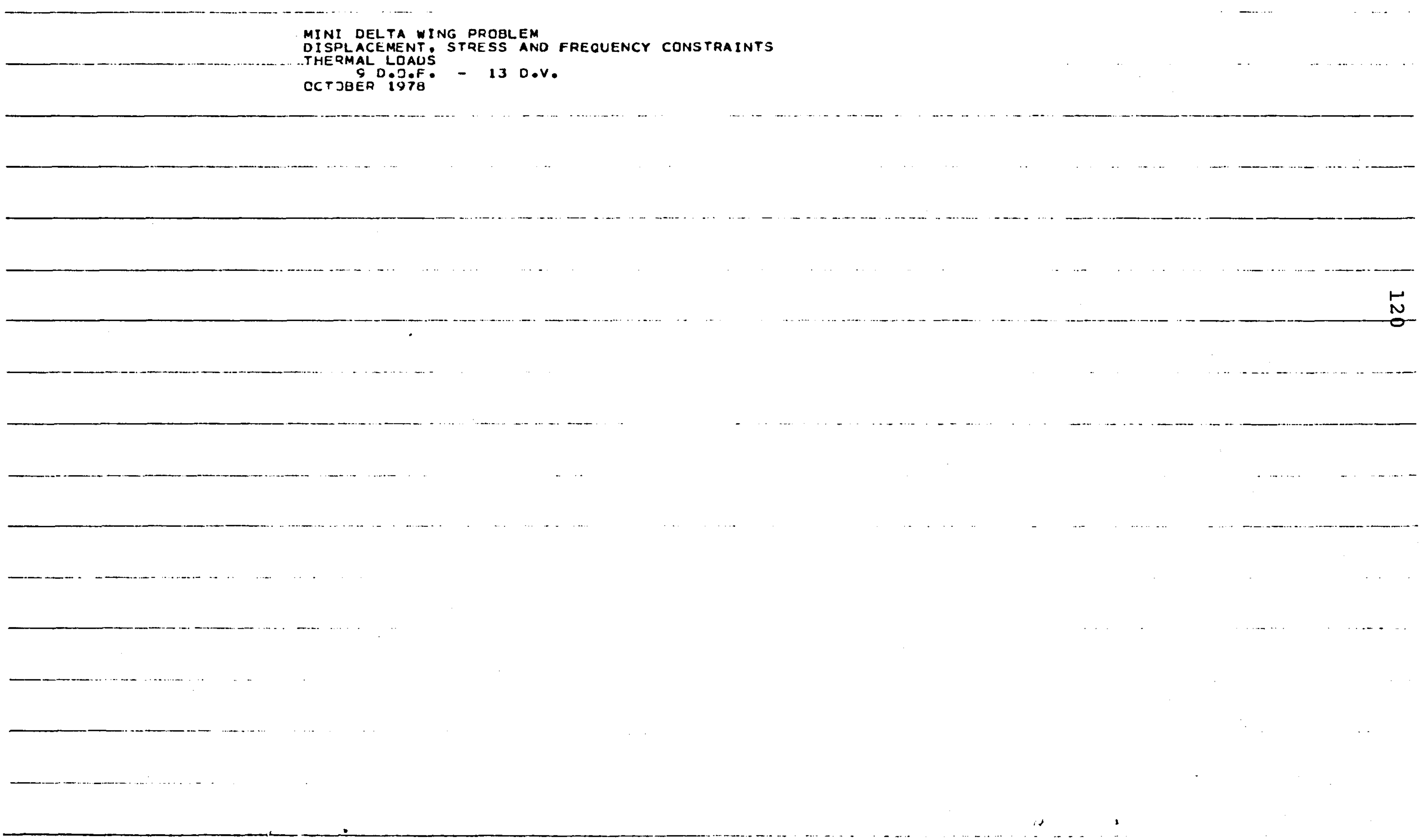
      MINI DELTA WING PROBLEM
      DISPLACEMENT, STRESS AND FREQUENCY CONSTRAINTS
      THERMAL LOADS
            9 D.O.F.    -   13 D.V.
      OCTOBER 1978
 1
      6       2       0       1       1       1       0
      6       3       2       1       4      13       2       0       2       0       0     200
      0       0      16       6       0       6
      1             0.0           960.0          6.468
      2             0.0           480.0         17.69
      3             0.0             0.0          5.492
      4           400.0           480.0          5.966
      5           400.0             0.0          5.143
      6           800.0             0.0          4.0
      1       1       1       1
      2       1       1       1
      3       1       1       1
      3
      1       1       2       4       0       1       1       1       0      -1      -1     999
      2       1       2       4       0       2       2       1       0      -2      -1     999
      3       1       2       4       0       2       2       1       0      -3      -1     999
      4       1       2       4       0       3       3       1       0      -4      -1     999
      5       2       5       4       0       4       4       1       0      -1      -1     999
      6       2       5       4       0       5       5       1       0      -2      -1     999
      7       2       5       4       0       5       5       1       0      -3      -1     999
      8       2       5       4       0       6       6       1       0      -4      -1     999
      9       2       3       5       0       4       4       1       0      -1      -1     999
     10       2       3       5       0       5       5       1       0      -2      -1     999
     11       2       3       5       0       5       5       1       0      -3      -1     999
     12       2       3       5       0       6       6       1       0      -4      -1     999
     13       4       5       6       0       7       7       1       0      -1      -1     999
     14       4       5       6       0       8       8       1       0      -2      -1     999
     15       4       5       6       0       8       8       1       0      -3      -1     999
     16       4       5       6       0       9       9       1       0      -4      -1     999
      4
      1       4       5       0       0       1      10       2       0       1      -1
      2       2       4       0       0       2      11       2       0       1      -1
      3       3       5       0       0       3      12       2       0       1      -1
      4       5       6       0       0       3      12       2       0       1      -1
      5       1       4       0       0       4      13       2       0       1      -1
      6       4       6       0       0       4      13       2       0       1      -1
      6
      1       4       5       0       0       1       2       2       0       1      -1
      2       2       4       0       0       2       2       2       0       1      -1
      3       3       5       0       0       3       2       2       0       1      -1
      4       5       6       0       0       3       2       2       0       1      -1
      5       1       4       0       0       4       2       2       0       1      -1
      6       4       6       0       0       4       2       2       0       1      -1
    0.40          0.35          0.10          1.25          0.75          0.25          0.20
    0.10          0.10          0.60          0.60          0.60          0.60
    0.0100E0      0.02
    0.1640E8      0.3           0.16         5.6000E-6  -0.1250E6     0.1250E5
    0.2100E8      0.1700E7      0.6500E6      0.2100E0     0.0560E0-0.2100E-5  0.1600E-4
    1.0           0.0           0.0          8.5714E-3-8.5714E-3  4.7059E-3-1.7647E-2
  1.8462E-2
    0.2100E8      0.1700E7      0.6500E6      0.2100E0     0.0560E0-0.2100E-6  0.1600E-4
    0.7071        0.7071        0.0          8.5714E-3-8.5714E-3  4.7059E-3-1.7647E-2
  1.8462E-2
    0.2100E8      0.1700E7      0.6500E6      0.2100E0     0.0560E0-0.2100E-6  0.1600E-4
   -0.7071        0.7071        0.0          8.5714E-3-8.5714E-3  4.7059E-3-1.7647E-2
  1.8462E-2
    0.2100E8      0.1700E7      0.6500E6      0.2100E0     0.0560E0-0.2100E-6  0.1600E-4
    0.0           1.0           0.0          8.5714E-3-8.5714E-3  4.7059E-3-1.7647E-2
  1.8462E-2
      3       3                                     LUMPED LOADS
      4             0.0             0.0       0.9421E5
      5             0.0             0.0       0.9421E5
      6             0.0             0.0       0.9421E5
      4            -0.0            -0.0      -0.9421E5
      5            -0.0            -0.0      -0.9421E5
      6            -0.0            -0.0      -0.9421E5
      0       0                                     INERTIA LOADS
      0       0      16       0       0       6
      1       1
      1       2       3       4       5       6       7       8       9      10      11      12      13      14
     15      16
      1       2       3       4       5       6
      1       1       1       1       1       1       1       1       1       1       1       1       1       1
      1       1
      2       2       2       2       2       2
      1       1       1       1       1       1       1       1       1       1       1       1       1       1
      1       1
      2       2       2       2       2       2
```

(2) 10 element delta wing

```
1.8462E-2
  0.2100E8  0.1700E7  0.6500E6  0.2100E0  0.0560E0-0.2100E-6 0.1600E-4
  0.0       1.0       0.0      8.5714E-3-8.5714E-3 4.7059E-3-1.7647E-2
1.8462E-2
    3    3                            LUMPED LOADS
    4       0.0       0.0       0.9421E5
    5       0.0       0.0       0.9421E5
    6       0.0       0.0       0.9421E5
    4      -0.0      -0.0      -0.9421E5
    5      -0.0      -0.0      -0.9421E5
    6      -0.0      -0.0      -0.9421E5
    0    0                            INERTIA LOADS
    0    0   16    0    0    6
    1    1
    1    2    3    4    5    6    7    8    9   10   11   12   13   14
   15   16
    1    2    3    4    5    6
    1    1    1    1    1    1    1    1    1    1    1    1    1    1
    1    1
    2    2    2    2    2    2
    1    1    1    1    1    1    1    1    1    1    1    1    1    1
    1    1
    2    2    2    2    2    2
 -2.0000E2 -1.0000E2
    0                                 FLIGHT CONDITIONS
    3                                 LUMPED MASSES
    4       2.1000E4
    5       1.5000E4
    6       1.2000E4
  0.0       0.0       0.0
    0                                 DISPLACEMENT CONSTRAINTS
    0                                 SLOPE CONSTRAINTS
    0    0    1    2
  0.1       0.9       1.0       1.5     0.1000E4  0.001
    1                                 FREQUENCY CONSTRAINTS
  0.1       0.8       1.0       1.2     1.0        0.1000E-3
   -1  0.4000E2
    0                                 FLUTTER CONSTRAINTS
    2   10   10  100    0
  0.0050    0.0001    0.0       0.0       5.0000E0
  0.75      1.2
2
    5    10   15   20   25   30   35   40   45   50   55   60   65   70
```


MINI DELTA WING PROBLEM
DISPLACEMENT, STRESS AND FREQUENCY CONSTRAINTS
THERMAL LOADS
9 D.O.F. - 13 D.V.
OCTOBER 1978

COMPLETE OPTIMIZATION BY DUAL1 OPTIMIZER

ANALYSIS PRINT OUT CONTROL = 2

DESIGN IN LINKED SIZING VARIABLE SPACE

NUMBER OF NODES	6
NUMBER OF TOTAL ELEMENTS	28
NUMBER OF LINKED VARIABLES	13
NUMBER OF LOAD CONDITIONS	2
NUMBER OF BOUNDARY NODES	3
NUMBER OF ISOTROPIC MATERIALS	1
NUMBER OF ORTHOTROPIC MATERIALS	4

	TRUSS	CST ISOTROPIC	CST ORTHOTROPIC	SSP	PSP	TSP	TBD	TBD	TBD	TBD
ELEMENTS	0	0	16	6	0	6				
LINKED VARIABLES	0	0	9	4	0	0				

NODE NUMBER	X	Y	Z
1	0.0	960.0000	6.4680
2	0.0	480.0000	17.6900
3	0.0	0.0	5.4920
4	400.0000	480.0000	5.9660
5	400.0000	0.0	5.1430
6	800.0000	0.0	4.0000

DISPLACEMENT BOUNDARY CONDITIONS

NODE NO.	BOUNDARY CODES* X	Y	Z	PRESCRIBED DISPLACEMENT X	Y	Z
1	1	1	1	0.0	0.0	0.0
2	1	1	1	0.0	0.0	0.0
3	1	1	1	0.0	0.0	0.0

* -1=PRESCRIBED, 0=FREE, 1=FIXED

ELEMENT NO.	N1	N2	N3	N4	LINKED GROUP	ELEMENT SIZE INITIAL	LOW.BD	UPP.BD	MATERIAL GROUP	SIDE CONSTRAINT CODE*
CONSTANT STRAIN TRIANGULAR - ORTHOTROPIC										
1	1	2	4		1	0.400000	0.010000	0.020000	-1	-1 999
2	1	2	4		2	0.350000	0.010000	0.020000	-2	-1 999
3	1	2	4		2	0.350000	0.010000	0.020000	-3	-1 999
4	1	2	4		3	0.100000	0.010000	0.020000	-4	-1 999
5	2	5	4		4	1.250000	0.010000	0.020000	-1	-1 999
6	2	5	4		5	0.750000	0.010000	0.020000	-2	-1 999
7	2	5	4		5	0.750000	0.010000	0.020000	-3	-1 999
8	2	5	4		6	0.250000	0.010000	0.020000	-4	-1 999
9	2	3	5		4	1.250000	0.010000	0.020000	-1	-1 999
10	2	3	5		5	0.750000	0.010000	0.020000	-2	-1 999
11	2	3	5		5	0.750000	0.010000	0.020000	-3	-1 999
12	2	3	5		6	0.250000	0.010000	0.020000	-4	-1 999
13	4	5	6		7	0.200000	0.010000	0.020000	-1	-1 999
14	4	5	6		8	0.100000	0.010000	0.020000	-2	-1 999
15	4	5	6		8	0.100000	0.010000	0.020000	-3	-1 999
16	4	5	6		9	0.100000	0.010000	0.020000	-4	-1 999

CONSTANT STRAIN TRIANGULAR - ORTHOTROPIC

1	1	2	4	1	0.400000	0.010000	0.020000	-1	-1	999
2	1	2	4	2	0.350000	0.010000	0.020000	-2	-1	999
3	1	2	4	2	0.350000	0.010000	0.020000	-3	-1	999
4	1	2	4	3	0.100000	0.010000	0.020000	-4	-1	999
5	2	5	4	4	1.250000	0.010000	0.020000	-1	-1	999
6	2	5	4	5	0.750000	0.010000	0.020000	-2	-1	999
7	2	5	4	5	0.750000	0.010000	0.020000	-3	-1	999
8	2	5	4	6	0.250000	0.010000	0.020000	-4	-1	999
9	2	3	5	4	1.250000	0.010000	0.020000	-1	-1	999
10	2	3	5	5	0.750000	0.010000	0.020000	-2	-1	999
11	2	3	5	5	0.750000	0.010000	0.020000	-3	-1	999
12	2	3	5	6	0.250000	0.010000	0.020000	-4	-1	999
13	4	5	6	7	0.200000	0.010000	0.020000	-1	-1	999
14	4	5	6	8	0.100000	0.010000	0.020000	-2	-1	999
15	4	5	6	8	0.100000	0.010000	0.020000	-3	-1	999
16	4	5	6	9	0.100000	0.010000	0.020000	-4	-1	999

SYMMETRIC SHEAR PANEL

1	4	5	1	0.600000	0.020000	0.020000	1	-1	0
2	2	4	2	0.600000	0.020000	0.020000	1	-1	0
3	3	5	3	0.600000	0.020000	0.020000	1	-1	0
4	5	6	3	0.600000	0.020000	0.020000	1	-1	0
5	1	4	4	0.600000	0.020000	0.020000	1	-1	0
6	4	6	4	0.600000	0.020000	0.020000	1	-1	0

THERMAL SYMMETRIC PANEL

1	4	5	1	0.350000	0.020000	0.020000	1	-1	0
2	2	4	2	0.350000	0.020000	0.020000	1	-1	0
3	3	5	3	0.350000	0.020000	0.020000	1	-1	0
4	5	6	3	0.350000	0.020000	0.020000	1	-1	0
5	1	4	4	0.350000	0.020000	0.020000	1	-1	0
6	4	6	4	0.350000	0.020000	0.020000	1	-1	0

* -2=FIXED AT INITIAL VALUE -1=LOWER BOUNDS ONLY
0=NON NEGATIVITY ONLY 1=UPPER BOUNDS ONLY
2=BOTH UPPER AND LOWER BOUNDS
SECOND NUMBER = DISCRETE VALUE GROUP NUMBER

MATERIAL CONSTANTS - ISOTROPIC MATERIALS

GROUP NO.	YOUNG'S MODULUS	POISSON'S RATIO	SPECIFIC WEIGHT	THERMAL EXPANSION.	COMPRESSIVE A. STRESS	TENSILE A. STRESS
1	16400000.0	0.3000	0.160000	0.00000560	-125000.0	125000.0

MATERIAL CONSTANTS - ORTHOTROPIC MATERIALS

GROUP NO.	YOUNG'S MODULUS (EL)	YOUNG'S MODULUS (ET)	SHEAR MODULUS (GLT)	POISSON'S RATIO (NULT)	SPECIFIC WEIGHT (GAMMA)	THERMAL EXPANSION (ALPHAL)	THERMAL EXPANSION (ALPHAT)	DIRECTION COSINES OF LONGITUDINAL AXIS X	Y	Z
-1	21000000.0	1700000.0	650000.0	0.210000	0.056000	-0.00000021	0.00001600	1.0000	0.0	0.0
-2	21000000.0	1700000.0	650000.0	0.210000	0.056000	-0.00000021	0.00001600	0.7071	0.7071	0.0
-3	21000000.0	1700000.0	650000.0	0.210000	0.056000	-0.00000021	0.00001600	-0.7071	0.7071	0.0
-4	21000000.0	1700000.0	650000.0	0.210000	0.056000	-0.00000021	0.00001600	0.0	1.0000	0.0

GROUP NO.	STRAIN TEN.LIMIT (EPSTL)	STRAIN COMP.LIMIT (EPSCL)	STRAIN TEN.LIMIT (EPSTT)	STRAIN COMP.LIMIT (EPSCT)	STRAIN SHEAR LIMIT (GAMMALT)	STRESS TEN.LONG. (FTL)	STRESS COMP.LONG. (FCL)	STRESS TEN.TRANS (FTT)	STRESS COMP.TRANS (FCT)	STRESS SHEAR (FLT)
-1	0.008571	-0.008571	0.004706	-0.017647	0.018462	0.0	0.0	0.0	0.0	0.0
-2	0.008571	-0.008571	0.004706	-0.017647	0.018462	0.0	0.0	0.0	0.0	0.0
-3	0.008571	-0.008571	0.004706	-0.017647	0.018462	0.0	0.0	0.0	0.0	0.0
-4	0.008571	-0.008571	0.004706	-0.017647	0.018462	0.0	0.0	0.0	0.0	0.0

LOAD CONDITIONS

LUMPED LOAD AT NODES

NODE NUMBER	X	Y	Z
LOAD CONDITION 1			
4	0.0	0.0	94210.0000
5	0.0	0.0	94210.0000

NO.	STRAIN TEN.LIMIT (EPSTL)	STRAIN COMP.LIMIT (EPSCL)	STRAIN TEN.LIMIT (EPSTT)	STRAIN COMP.LIMIT (EPSCT)	STRAIN SHEAR LIMIT (GAMMALT)	STRESS TEN.LONG. (FTL)	STRESS COMP.LONG. (FCL)	STRESS TEN.TRANS (FTT)	STRESS COMP.TRANS (FCT)	STRESS SHEAR (FLT)
-1	0.008571	-0.008571	0.004706	-0.017647	0.018462	0.0	0.0	0.0	0.0	0.0
-2	0.008571	-0.008571	0.004706	-0.017647	0.018462	0.0	0.0	0.0	0.0	0.0
-3	0.008571	-0.008571	0.004706	-0.017647	0.018462	0.0	0.0	0.0	0.0	0.0
-4	0.008571	-0.008571	0.004706	-0.017647	0.018462	0.0	0.0	0.0	0.0	0.0

LOAD CONDITIONS

LUMPED LOAD AT NODES

NODE NUMBER	X	Y	Z
LOAD CONDITION 1			
4	0.0	0.0	94210.0000
5	0.0	0.0	94210.0000
6	0.0	0.0	94210.0000
LOAD CONDITION 2			
4	0.0	0.0	-94210.0000
5	0.0	0.0	-94210.0000
6	0.0	0.0	-94210.0000

PRESSURE LOAD

NO PRESSURE LOAD SPECIFIED

GRAVITY LOAD

LOAD CONDITION NO.	MAGNITUDE(G)	DIRECTION COSINES
0	NO GRAVITY LOAD	

THERMAL LOAD

ELEMENT TYPE	ELEMENT NUMBER	THERMAL LOAD GROUP NUMBER / LOAD CONDITIONS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
3	1	1	1																		
3	2	1	1																		
3	3	1	1																		
3	4	1	1																		
3	5	1	1																		
3	6	1	1																		
3	7	1	1																		
3	8	1	1																		
3	9	1	1																		
3	10	1	1																		
3	11	1	1																		
3	12	1	1																		
3	13	1	1																		
3	14	1	1																		
3	15	1	1																		
3	16	1	1																		
6	1	2	2																		
6	2	2	2																		
6	3	2	2																		
6	4	2	2																		
6	5	2	2																		
6	6	2	2																		

THERMAL LOAD MAGNITUDE

-200.0000 -100.0000

3	15	1	1
3	16	1	1
6	1	2	2
6	2	2	2
6	3	2	2
6	4	2	2
6	5	2	2
6	6	2	2

THERMAL LOAD MAGNITUDE

-200.0000 -100.0000

NON-STRUCTURAL MASS

NODE NUMBER	WEIGHT OF LUMPED MASS
4	21000.0000
5	15000.0000
6	12000.0000

CONSTRAINT DATA

SIDE CONSTRAINTS

SIDE CONSTRAINT SPECIFICATIONS ARE GIVEN IN THE ELEMENT DATA

DISPLACEMENT CONSTRAINTS

NO DISPLACEMENT CONSTRAINTS

SLOPE/RELATIVE DISPLACEMENT CONSTRAINTS

NC SLOPE CONSTRAINTS

STRESS/STRAIN CONSTRAINTS

INITIAL TRUNCATION FACTOR	0.1000
MAXIMUM TRUNCATION FACTOR	0.9000
BASIS CUTOFF FACTOR	1.0000
MULTIPLIER FOR TRF UPDATING	1.5000
MINIMUM NORMALIZATION FACTOR	
STRESS	1000.0000
STRAIN	0.100000E-02

NO EULER BUCKLING CONSTRAINTS IMPOSED

ELEMENT TYPE 1
NO STRESS/STRAIN CONSTRAINTS SPECIFIED

ELEMENT TYPE 2
NO STRESS/STRAIN CONSTRAINTS SPECIFIED

ELEMENT TYPE 3

ALL ELEMENTS ARE SUBJECT TO STRAIN ENVELOPE CONSTRAINTS

ELEMENT TYPE 4

ALL ELEMENTS ARE CONSTRAINED BY UPPER BOUNDS ONLY

ELEMENT TYPE 5
NO STRESS/STRAIN CONSTRAINTS SPECIFIED

ELEMENT TYPE 6
NO STRESS/STRAIN CONSTRAINTS SPECIFIED

ELEMENT TYPE 2
NO STRESS/STRAIN CONSTRAINTS SPECIFIED

ELEMENT TYPE 3

ALL ELEMENTS ARE SUBJECT TO STRAIN ENVELOPE CONSTRAINTS

ELEMENT TYPE 4

ALL ELEMENTS ARE CONSTRAINED BY UPPER BOUNDS ONLY

ELEMENT TYPE 5
NO STRESS/STRAIN CONSTRAINTS SPECIFIED

ELEMENT TYPE 6
NO STRESS/STRAIN CONSTRAINTS SPECIFIED

FREQUENCY CONSTRAINTS

B-SPACE FIRST ORDER EXPANSION

INITIAL TRUNCATION FACTOR	0.1000
MAXIMUM TRUNCATION FACTOR	0.8000
BASIS CUTOFF FACTOR	1.0000
MULTIPLIER FOR TRF UPDATING	1.2000
MINIMUM NORMALIZATION FACTOR	1.0000

CONVERGENCE CRITERIA	0.100000E-03
ACCELELATION OF GRAVITY	0.386070E+03

FREQUENCY NO.	CODE*	LOWER BOUND	UPPER BOUND
1	-1	40.00000	0.0

*-1=LOWER BOUND ONLY, 0=NO CONSTRAINTS
1=UPPER BOUND ONLY, 2=LOWER AND UPPER BOUNDS

OPTIMIZER CONTROL PARAMETERS

DUAL 1

PRINT OUT CONTROL	2
MAX. NO. OF STAGES	10
MAX. NO. OF RESTARTS	10
MAX. NO. OF ONE DIM. MIN. / RESTART	100
COMBINATORIAL METHOD (DISCRETE CASE)	0
DIMINISHING RETURN CRITERION AMONG STAGES	0.5000E-02
DIMINISHING RETURN CRITERION AMONG O.D.M.	0.1000E-03
MAX. STEP SIZE ALLOWED IN A SINGLE STAGE	0.5000E+01
STEP SIZE MODIFICATION FACTOR	0.7500E+00
STEP SIZE MINIMUM ALLOWABLE	0.1200E+01
STEP SIZE IN DUAL SPACE	0.0

CONSTRAINT IDENTIFICATION CODES

CONSTRAINT TYPE 1 13 CONSTRAINTS IN THIS TYPE

99930001	99930002	99930004	99930005	99930006	99930008	99930013	99930014	99930016	-40001
-40002	-40003	-40005							

CONSTRAINT TYPE 2 0 CONSTRAINTS IN THIS TYPE

CONSTRAINT TYPE 3 0 CONSTRAINTS IN THIS TYPE

CONSTRAINT TYPE 4 172 CONSTRAINTS IN THIS TYPE

-11030001	11030001	-12030001	12030001	13030001	-11030002	11030002	-12030002	12030002	13030002
-11030003	11030003	-12030003	12030003	13030003	-11030004	11030004	-12030004	12030004	13030004
-11030005	11030005	-12030005	12030005	13030005	-11030006	11030006	-12030006	12030006	13030006
-11030007	11030007	-12030007	12030007	13030007	-11030008	11030008	-12030008	12030008	13030008
-11030009	11030009	-12030009	12030009	13030009	-11030010	11030010	-12030010	12030010	13030010
-11030011	11030011	-12030011	12030011	13030011	-11030012	11030012	-12030012	12030012	13030012
-11030013	11030013	-12030013	12030013	13030013	-11030014	11030014	-12030014	12030014	13030014
-11030015	11030015	-12030015	12030015	13030015	-11030016	11030016	-12030016	12030016	13030016
10040001	10040002	10040003	10040004	10040005	10040006	-21030001	21030001	-22030001	22030001
23030001	-21030002	21030002	-22030002	22030002	23030002	-21030003	21030003	-22030003	22030003
23030003	-21030004	21030004	-22030004	22030004	23030004	-21030005	21030005	-22030005	22030005
23030005	-21030006	21030006	-22030006	22030006	23030006	-21030007	21030007	-22030007	22030007
23030007	-21030008	21030008	-22030008	22030008	23030008	-21030009	21030009	-22030009	22030009
23030009	-21030010	21030010	-22030010	22030010	23030010	-21030011	21030011	-22030011	22030011
23030011	-21030012	21030012	-22030012	22030012	23030012	-21030013	21030013	-22030013	22030013
23030013	-21030014	21030014	-22030014	22030014	23030014	-21030015	21030015	-22030015	22030015
23030015	-21030016	21030016	-22030016	22030016	23030016	20040001	20040002	20040003	20040004
20040005	20040006								

```
CONSTRAINT TYPE  4          172  CONSTRAINTS IN THIS TYPE
  -11030001  11030001 -12030001  12030001  13030001 -11030002  11030002 -12030002  12030002  13030002
  -11030003  11030003 -12030003  12030003  13030003 -11030004  11030004 -12030004  12030004  13030004
  -11030005  11030005 -12030005  12030005  13030005 -11030006  11030006 -12030006  12030006  13030006
  -11030007  11030007 -12030007  12030007  13030007 -11030008  11030008 -12030008  12030008  13030008
  -11030009  11030009 -12030009  12030009  13030009 -11030010  11030010 -12030010  12030010  13030010
  -11030011  11030011 -12030011  12030011  13030011 -11030012  11030012 -12030012  12030012  13030012
  -11030013  11030013 -12030013  12030013  13030013 -11030014  11030014 -12030014  12030014  13030014
  -11030015  11030015 -12030015  12030015  13030015 -11030016  11030016 -12030016  12030016  13030016
   10040001  10040002  10040003  10040004  10040005  10040006 -21030001  21030001 -22030001  22030001
   23030001 -21030002  21030002 -22030002  22030002  23030002 -21030003  21030003 -22030003  22030003
   23030003 -21030004  21030004 -22030004  22030004  23030004 -21030005  21030005 -22030005  22030005
   23030005 -21030006  21030006 -22030006  22030006  23030006 -21030007  21030007 -22030007  22030007
   23030007 -21030008  21030008 -22030008  22030008  23030008 -21030009  21030009 -22030009  22030009
   23030009 -21030010  21030010 -22030010  22030010  23030010 -21030011  21030011 -22030011  22030011
   23030011 -21030012  21030012 -22030012  22030012  23030012 -21030013  21030013 -22030013  22030013
   23030013 -21030014  21030014 -22030014  22030014  23030014 -21030015  21030015 -22030015  22030015
   23030015 -21030016  21030016 -22030016  22030016  23030016  20040001  20040002  20040003  20040004
   20040005  20040006

CONSTRAINT TYPE  5            1  CONSTRAINTS IN THIS TYPE
        -1

CONSTRAINT TYPE  6            0  CONSTRAINTS IN THIS TYPE

NUMBER OF BEHAVIOUR CONSTRAINTS  173

NUMBER OF DESIGN VARIABLES        13

NUMBER OF DISCRETE VARIABLES       9

                         END OVERLAY PREP00

                         ENTER OVERLAY DESIGN
```



```
-------------------------------------------
STAGE NO.  1    APPROXIMATE PROBLEM GENERATOR
-------------------------------------------

CURRENT MEMBER SIZE
-------------------
 MEMBER TYPE NUMBER  3
   0.4000E+00  0.3500E+00  0.3500E+00  0.1000E+00  0.1250E+01  0.7500E+00  0.7500E+00  0.2500E+00  0.1250E+01  0.7500E+00
   0.7500E+00  0.2500E+00  0.2000E+00  0.1000E+00  0.1000E+00  0.1000E+00
 MEMBER TYPE NUMBER  4
   0.6000E+00  0.6000E+00  0.6000E+00  0.6000E+00  0.6000E+00  0.6000E+00
```

STAGE NO. 1   APPROXIMATE PROBLEM GENERATOR

CURRENT MEMBER SIZE

MEMBER TYPE NUMBER 3
0.4000E+00 0.3500E+00 0.3500E+00 0.1000E+00 0.1250E+01 0.7500E+00 0.7500E+00 0.2500E+00 0.1250E+01 0.7500E+00
0.7500E+00 0.2500E+00 0.2000E+00 0.1000E+00 0.1000E+00 0.1000E+00
MEMBER TYPE NUMBER 4
0.6000E+00 0.6000E+00 0.6000E+00 0.6000E+00 0.6000E+00 0.6000E+00
MEMBER TYPE NUMBER 6
0.6000E+00 0.6000E+00 0.6000E+00 0.6000E+00 0.6000E+00 0.6000E+00

CURRENT WEIGHT DATA

MEMBER TYPE NUMBER 3 WEIGHT = 0.414119E+05
MEMBER TYPE NUMBER 4 WEIGHT = 0.176169E+04

VARIABLE STRUCTURAL WEIGHT 0.431736E+05
FIXED STRUCTURAL WEIGHT 0.0
TOTAL STRUCTURAL WEIGHT 0.431736E+05
NON-STRUCTURAL WEIGHTHT 0.480000E+05

TOTAL WEIGHT 0.911736E+05

CONVERGENCE CHECK   STAGE NO.= 1   0.2316E+26   0.1000E+01   MUST BE LESS THAN 0.500000E-02
OBJECTIVE FUNCTION OF THREE CONSECUTIVE STAGES ARE 0.200000E+31 0.100000E+31 0.431736E+05

ENTER OVERLAY ANALYS

NODAL DISPLACEMENTS

NODE	X	Y	Z	NODE	X	Y	Z
LOAD CONDITION 1							
1	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	4	-0.48375E-01	0.57807E-01	0.23022E+01
5	-0.23434E+00	0.70071E-01	0.91633E+01	6	-0.11012E+01	0.36850E+00	0.69293E+02

LOAD CONDITION 2

NODAL DISPLACEMENTS

NODE	X	Y	Z	NODE	X	Y	Z
LOAD CONDITION 1							
1	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	4	-0.48375E-01	0.57807E-01	0.23022E+01
5	-0.23434E+00	0.70071E-01	0.91633E+01	6	-0.11012E+01	0.36850E+00	0.69293E+02
LOAD CONDITION 2							
1	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	4	0.48375E-01	-0.57807E-01	-0.23022E+01
5	0.23434E+00	-0.70071E-01	-0.91633E+01	6	0.11012E+01	-0.36850E+00	-0.69293E+02

NODAL DISPLACEMENTS

NODE	X	Y	Z	NODE	X	Y	Z
LOAD CONDITION 1							
1	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	4	-0.34813E-01	-0.96274E-01	-0.54249E-02
5	-0.78961E-01	0.10947E+00	-0.36802E-02	6	-0.13376E+00	0.81952E-01	-0.23098E-02
LOAD CONDITION 2							

NODAL DISPLACEMENTS

NODE	X	Y	Z	NODE	X	Y	Z
LOAD CONDITION 1							
1	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	4	-0.34813E-01	-0.96274E-01	-0.54249E-02
5	-0.78961E-01	0.10947E+00	-0.36802E-02	6	-0.13376E+00	0.81952E-01	-0.23098E-02
LOAD CONDITION 2							
1	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	4	-0.34813E-01	-0.96274E-01	-0.54249E-02
5	-0.78961E-01	0.10947E+00	-0.36802E-02	6	-0.13376E+00	0.81952E-01	-0.23098E-02

NEW AVAILABLE REAL ARRAY = 7473

```
EIGEN VECTORS SCALED BY MAX. COMPONENTS
  VECTOR NO.=    1      FREQUENCY=   0.100863E+01 C/S
   -0.4982E-03  0.6857E-03  0.2227E-01 -0.3075E-02  0.9783E-03  0.1115E+00 -0.1662E-01  0.5249E-02  0.1000E+01
  VECTOR NO.=    2      FREQUENCY=   0.331536E+01 C/S
   -0.4632E-02  0.5255E-02  0.2572E+00 -0.1389E-01  0.8978E-02  0.1000E+01  0.4398E-01  0.1313E-01 -0.4307E+00
  VECTOR NO.=    3      FREQUENCY=   0.608329E+01 C/S
   -0.1858E-01  0.6063E-02  0.1000E+01  0.4682E-02 -0.3427E-01 -0.4144E+00 -0.1285E-01 -0.5324E-01 -0.2432E-01

****************************************** EIGEN ANALYSIS CONVERGED IN   2 ITERATIONS ******************************************

EIGEN VALUES
     0.4016E+02  0.4339E+03  0.1461E+04

EIGEN VECTORS SCALED BY UMU
  VECTOR NO.=    1      FREQUENCY=   0.100863E+01 C/S
   -0.8080E-04  0.1112E-03  0.3612E-02 -0.4987E-03  0.1587E-03  0.1808E-01 -0.2696E-02  0.8513E-03  0.1622E+00
```

MTYP	M	LC	S-COMBINED	SX	SY	SXY	SX-THERM	SY-THERM	SXY-THERM
3	1	1		-0.2894E-03	-0.6953E-08	-0.1035E-04			
3	1	1		-0.4179E-03	0.3200E-02	0.2297E-03	-0.1286E-03	0.3200E-02	0.2401E-03
3	2	1		-0.1396E-03	-0.1497E-03	-0.2894E-03			
3	2	1		-0.3449E-03	0.3127E-02	-0.3759E-03	-0.2053E-03	0.3277E-02	-0.8652E-04
3	3	1		-0.1498E-03	-0.1396E-03	0.2894E-03			
3	3	1		-0.1149E-03	0.2897E-02	0.3760E-03	0.3487E-04	0.3037E-02	0.8660E-04
3	4	1		0.5401E-12	-0.2894E-03	0.9955E-05			
3	4	1		-0.4200E-04	0.2824E-02	-0.2302E-03	-0.4200E-04	0.3114E-02	-0.2402E-03
3	5	1		-0.2894E-03	-0.5001E-04	-0.9603E-03			
3	5	1		-0.4179E-03	0.2721E-02	-0.8118E-03	-0.1286E-03	0.2771E-02	0.1486E-03
3	6	1		0.3104E-03	-0.6498E-03	-0.2397E-03			
3	6	1		-0.6340E-04	0.2367E-02	0.1024E-03	-0.3738E-03	0.3017E-02	0.3421E-03
3	7	1		-0.6499E-03	0.3105E-03	0.2389E-03			
3	7	1		-0.8751E-03	0.3179E-02	-0.1031E-03	-0.2252E-03	0.2868E-02	-0.3420E-03
3	8	1		-0.5006E-04	-0.2893E-03	0.9603E-03			
3	8	1		-0.5207E-03	0.2824E-02	0.8117E-03	-0.4706E-03	0.3113E-02	-0.1486E-03
3	9	1		-0.6058E-03	0.1678E-07	-0.7571E-03			
3	9	1		-0.8452E-03	0.3200E-02	-0.1030E-02	-0.2394E-03	0.3200E-02	-0.2733E-03
3	10	1		0.7573E-04	-0.6815E-03	-0.6056E-03			
3	10	1		0.7174E-04	0.2283E-02	-0.8029E-03	-0.3988E-05	0.2965E-02	-0.1973E-03
3	11	1		-0.6813E-03	0.7553E-04	0.6061E-03			
3	11	1		-0.9587E-03	0.3313E-02	0.8036E-03	-0.2773E-03	0.3238E-02	0.1975E-03
3	12	1		-0.1065E-08	-0.6058E-03	0.7571E-03			
3	12	1		-0.4200E-04	0.2397E-02	0.1030E-02	-0.4200E-04	0.3003E-02	0.2734E-03
3	13	1		-0.2597E-02	-0.5005E-04	-0.1432E-02			
3	13	1		-0.2776E-02	0.2721E-02	-0.1455E-02	-0.1790E-03	0.2771E-02	-0.2319E-04
3	14	1		-0.6073E-03	-0.2039E-02	-0.2547E-02			
3	14	1		-0.9205E-03	0.8662E-03	-0.2255E-02	-0.3132E-03	0.2906E-02	0.2916E-03
3	15	1		-0.2039E-02	-0.6073E-03	0.2547E-02			
3	15	1		-0.2376E-02	0.2321E-02	0.2255E-02	-0.3364E-03	0.2929E-02	-0.2916E-03
3	16	1		-0.5006E-04	-0.2597E-02	0.1432E-02			
3	16	1		-0.5207E-03	0.4664E-03	0.1455E-02	-0.4706E-03	0.3063E-02	0.2319E-04
4	1	1	0.304057E+05	-0.4190E+03	0.0	0.1755E+05			

3	9	1		-0.8452E-03	0.3200E-02	-0.1030E-02	-0.2394E-03	0.3200E-02	-0.2733E-03
3	10	1		0.7573E-04	-0.6815E-03	-0.6056E-03			
3	10	1		0.7174E-04	0.2283E-02	-0.8029E-03	-0.3988E-05	0.2965E-02	-0.1973E-03
3	11	1		-0.6813E-03	0.7553E-04	0.6061E-03			
3	11	1		-0.9587E-03	0.3313E-02	0.8036E-03	-0.2773E-03	0.3238E-02	0.1975E-03
3	12	1		-0.1065E-08	-0.6058E-03	0.7571E-03			
3	12	1		-0.4200E-04	0.2397E-02	0.1030E-02	-0.4200E-04	0.3003E-02	0.2734E-03
3	13	1		-0.2597E-02	-0.5005E-04	-0.1432E-02			
3	13	1		-0.2776E-02	0.2721E-02	-0.1455E-02	-0.1790E-03	0.2771E-02	-0.2319E-04
3	14	1		-0.6073E-03	-0.2039E-02	-0.2547E-02			
3	14	1		-0.9205E-03	0.8662E-03	-0.2255E-02	-0.3132E-03	0.2906E-02	0.2916E-03
3	15	1		-0.2039E-02	-0.6073E-03	0.2547E-02			
3	15	1		-0.2376E-02	0.2321E-02	0.2255E-02	-0.3364E-03	0.2929E-02	-0.2916E-03
3	16	1		-0.5006E-04	-0.2597E-02	0.1432E-02			
3	16	1		-0.5207E-03	0.4664E-03	0.1455E-02	-0.4706E-03	0.3063E-02	0.2319E-04
4	1	1	0.304057E+05	-0.4190E+03	0.0	0.1755E+05			
6	1	1	0.307008E+05	0.5448E+03	-0.3969E+04	0.1755E+05	0.9638E+03	-0.3969E+04	0.0
4	2	1	0.405860E+05	-0.1983E+04	0.0	0.2340E+05			
6	2	1	0.414035E+05	0.8328E+04	0.8517E+04	0.2340E+05	0.1031E+05	0.8517E+04	0.0
4	3	1	0.135441E+05	-0.9608E+04	0.0	0.5512E+04			
6	3	1	0.118229E+05	-0.1916E+04	0.5816E+04	0.5512E+04	0.7691E+04	0.5816E+04	0.0
4	4	1	0.585200E+05	-0.3554E+05	0.0	0.2684E+05			
6	4	1	0.546482E+05	-0.2843E+05	0.5723E+03	0.2684E+05	0.7109E+04	0.5723E+03	0.0
4	5	1	0.260525E+05	-0.1978E+04	0.0	-0.1500E+05			
6	5	1	0.274643E+05	0.1027E+05	0.5704E+04	-0.1500E+05	0.1225E+05	0.5704E+04	0.0
4	6	1	0.245984E+05	-0.2396E+05	0.0	0.3227E+04			
6	6	1	0.204168E+05	-0.2081E+05	-0.2600E+04	0.3227E+04	0.3148E+04	-0.2600E+04	0.0
3	1	2		0.2894E-03	0.6953E-08	0.1035E-04			
3	1	2		0.1608E-03	0.3200E-02	0.2504E-03	-0.1286E-03	0.3200E-02	0.2401E-03
3	2	2		0.1396E-03	0.1497E-03	0.2894E-03			
3	2	2		-0.6564E-04	0.3427E-02	0.2029E-03	-0.2053E-03	0.3277E-02	-0.8652E-04
3	3	2		0.1498E-03	0.1396E-03	-0.2894E-03			
3	3	2		0.1847E-03	0.3176E-02	-0.2028E-03	0.3487E-04	0.3037E-02	0.8660E-04
3	4	2		-0.5401E-12	0.2894E-03	-0.9955E-05			
3	4	2		-0.4200E-04	0.3403E-02	-0.2502E-03	-0.4200E-04	0.3114E-02	-0.2402E-03
3	5	2		0.2894E-03	0.5001E-04	0.9603E-03			
3	5	2		0.1608E-03	0.2821E-02	0.1109E-02	-0.1286E-03	0.2771E-02	0.1486E-03
3	6	2		-0.3104E-03	0.6498E-03	0.2397E-03			
3	6	2		-0.6842E-03	0.3666E-02	0.5819E-03	-0.3738E-03	0.3017E-02	0.3421E-03
3	7	2		0.6499E-03	-0.3105E-03	-0.2389E-03			
3	7	2		0.4247E-03	0.2558E-02	-0.5809E-03	-0.2252E-03	0.2868E-02	-0.3420E-03
3	8	2		0.5006E-04	0.2893E-03	-0.9603E-03			
3	8	2		-0.4206E-03	0.3403E-02	-0.1109E-02	-0.4706E-03	0.3113E-02	-0.1486E-03
3	9	2		0.6058E-03	-0.1678E-07	0.7571E-03			
3	9	2		0.3664E-03	0.3200E-02	0.4837E-03	-0.2394E-03	0.3200E-02	-0.2733E-03
3	10	2		-0.7573E-04	0.6815E-03	0.6056E-03			
3	10	2		-0.7972E-04	0.3646E-02	0.4083E-03	-0.3988E-05	0.2965E-02	-0.1973E-03
3	11	2		0.6813E-03	-0.7553E-04	-0.6061E-03			
3	11	2		0.4040E-03	0.3162E-02	-0.4086E-03	-0.2773E-03	0.3238E-02	0.1975E-03
3	12	2		0.1065E-08	0.6058E-03	-0.7571E-03			
3	12	2		-0.4200E-04	0.3608E-02	-0.4837E-03	-0.4200E-04	0.3003E-02	0.2734E-03
3	13	2		0.2597E-02	0.5005E-04	0.1432E-02			
3	13	2		0.2418E-02	0.2821E-02	0.1409E-02	-0.1790E-03	0.2771E-02	-0.2319E-04
3	14	2		0.6073E-03	0.2039E-02	0.2547E-02			
3	14	2		0.2941E-03	0.4945E-02	0.2838E-02	-0.3132E-03	0.2906E-02	0.2916E-03
3	15	2		0.2039E-02	0.6073E-03	-0.2547E-02			
3	15	2		0.1703E-02	0.3536E-02	-0.2838E-02	-0.3364E-03	0.2929E-02	-0.2916E-03
3	16	2		0.5006E-04	0.2597E-02	-0.1432E-02			
3	16	2		-0.4206E-03	0.5660E-02	-0.1409E-02	-0.4706E-03	0.3063E-02	0.2319E-04
4	1	2	0.304057E+05	0.4190E+03	0.0	-0.1755E+05			
6	1	2	0.307812E+05	0.1383E+04	-0.3969E+04	-0.1755E+05	0.9638E+03	-0.3969E+04	0.0
4	2	2	0.405860E+05	0.1983E+04	0.0	-0.2340E+05			
6	2	2	0.419795E+05	0.1229E+05	0.8517E+04	-0.2340E+05	0.1031E+05	0.8517E+04	0.0
4	3	2	0.135441E+05	0.9608E+04	0.0	-0.5512E+04			
6	3	2	0.179892E+05	0.1730E+05	0.5816E+04	-0.5512E+04	0.7691E+04	0.5816E+04	0.0
4	4	2	0.585200E+05	0.3554E+05	0.0	-0.2684E+05			
6	4	2	0.628994E+05	0.4265E+05	0.5723E+03	-0.2684E+05	0.7109E+04	0.5723E+03	0.0
4	5	2	0.260525E+05	0.1978E+04	0.0	0.1500E+05			
6	5	2	0.287868E+05	0.1423E+05	0.5704E+04	0.1500E+05	0.1225E+05	0.5704E+04	0.0
4	6	2	0.245984E+05	0.2396E+05	0.0	-0.3227E+04			
6	6	2	0.290347E+05	0.2710E+05	-0.2600E+04	-0.3227E+04	0.3148E+04	-0.2600E+04	0.0

172 STRESS/STRAIN CONSTRAINTS 1 TO 172 MOST CRITICAL CONSTRAINT= -0.2026535E+00

0.9512E+00	0.1049E+01	0.1181E+01	0.3200E+00	0.9876E+00	0.9598E+00	0.1040E+01	0.1177E+01	0.3355E+00	0.9796E+00
0.9366E+00	0.1013E+01	0.1164E+01	0.3844E+00	0.9796E+00	0.9951E+00	0.1005E+01	0.1160E+01	0.3999E+00	0.9875E+00
0.9512E+00	0.1049E+01	0.1154E+01	0.4217E+00	0.9560E+00	0.9926E+00	0.1007E+01	0.1134E+01	0.4971E+00	0.9945E+00
0.8979E+00	0.1102E+01	0.1180E+01	0.3246E+00	0.9944E+00	0.9393E+00	0.1061E+01	0.1160E+01	0.3999E+00	0.9560E+00
0.9014E+00	0.1099E+01	0.1181E+01	0.3200E+00	0.9442E+00	0.1008E+01	0.9916E+00	0.1129E+01	0.5149E+00	0.9565E+00
0.8882E+00	0.1112E+01	0.1188E+01	0.2959E+00	0.9565E+00	0.9951E+00	0.1005E+01	0.1136E+01	0.4907E+00	0.9442E+00
0.6762E+00	0.1324E+01	0.1154E+01	0.4217E+00	0.9212E+00	0.8926E+00	0.1107E+01	0.1049E+01	0.8159E+00	0.8779E+00
0.7228E+00	0.1277E+01	0.1132E+01	0.5067E+00	0.8779E+00	0.9393E+00	0.1061E+01	0.1026E+01	0.9009E+00	0.9212E+00
0.7544E+00	0.6688E+00	0.9054E+00	0.5628E+00	0.7803E+00	0.8367E+00	0.1019E+01	0.9812E+00	0.1181E+01	0.3200E+00
0.9864E+00	0.9923E+00	0.1008E+01	0.1194E+01	0.2718E+00	0.9890E+00	0.1022E+01	0.9785E+00	0.1180E+01	0.3250E+00
0.9890E+00	0.9951E+00	0.1005E+01	0.1193E+01	0.2769E+00	0.9865E+00	0.1019E+01	0.9812E+00	0.1160E+01	0.4005E+00
0.9399E+00	0.9202E+00	0.1080E+01	0.1208E+01	0.2209E+00	0.9685E+00	0.1050E+01	0.9505E+00	0.1145E+01	0.4565E+00
0.9665E+00	0.9509E+00	0.1049E+01	0.1193E+01	0.2769E+00	0.9399E+00	0.1043E+01	0.9572E+00	0.1181E+01	0.3200E+00
0.9738E+00	0.9907E+00	0.1009E+01	0.1207E+01	0.2252E+00	0.9779E+00	0.1047E+01	0.9529E+00	0.1179E+01	0.3280E+00
0.9779E+00	0.9951E+00	0.1005E+01	0.1204E+01	0.2332E+00	0.9738E+00	0.1282E+01	0.7179E+00	0.1160E+01	0.4005E+00

6	3	2	0.179892E+05	0.1730E+05	0.5816E+04	-0.5512E+04	0.7691E+04	0.5816E+04	0.0
4	4	2	0.585200E+05	0.3554E+05	0.0	-0.2684E+05			
6	4	2	0.628994E+05	0.4265E+05	0.5723E+03	-0.2684E+05	0.7109E+04	0.5723E+03	0.0
4	5	2	0.260525E+05	0.1978E+04	0.0	0.1500E+05			
6	5	2	0.287868E+05	0.1423E+05	0.5704E+04	0.1500E+05	0.1225E+05	0.5704E+04	0.0
4	6	2	0.245984E+05	0.2396E+05	0.0	-0.3227E+04			
6	6	2	0.290347E+05	0.2710E+05	-0.2600E+04	-0.3227E+04	0.3148E+04	-0.2600E+04	0.0

172 STRESS/STRAIN CONSTRAINTS 1 TO 172 MOST CRITICAL CONSTRAINT= -0.2026535E+00

0.9512E+00	0.1049E+01	0.1181E+01	0.3200E+00	0.9876E+00	0.9598E+00	0.1040E+01	0.1177E+01	0.3355E+00	0.9796E+00
0.9366E+00	0.1013E+01	0.1164E+01	0.3844E+00	0.9796E+00	0.9951E+00	0.1005E+01	0.1160E+01	0.3999E+00	0.9875E+00
0.9512E+00	0.1049E+01	0.1154E+01	0.4217E+00	0.9560E+00	0.9926E+00	0.1007E+01	0.1134E+01	0.4971E+00	0.9945E+00
0.8979E+00	0.1102E+01	0.1180E+01	0.3246E+00	0.9944E+00	0.9393E+00	0.1061E+01	0.1160E+01	0.3999E+00	0.9560E+00
0.9014E+00	0.1099E+01	0.1181E+01	0.3200E+00	0.9442E+00	0.1008E+01	0.9916E+00	0.1129E+01	0.5149E+00	0.9565E+00
0.8882E+00	0.1112E+01	0.1188E+01	0.2959E+00	0.9565E+00	0.9951E+00	0.1005E+01	0.1136E+01	0.4907E+00	0.9442E+00
0.6762E+00	0.1324E+01	0.1154E+01	0.4217E+00	0.9212E+00	0.8926E+00	0.1107E+01	0.1049E+01	0.8159E+00	0.8779E+00
0.7228E+00	0.1277E+01	0.1132E+01	0.5067E+00	0.8779E+00	0.9393E+00	0.1061E+01	0.1026E+01	0.9009E+00	0.9212E+00
0.7544E+00	0.6688E+00	0.9054E+00	0.5628E+00	0.7803E+00	0.8367E+00	0.1019E+01	0.9812E+00	0.1181E+01	0.3200E+00
0.9864E+00	0.9923E+00	0.1008E+01	0.1194E+01	0.2718E+00	0.9890E+00	0.1022E+01	0.9785E+00	0.1180E+01	0.3250E+00
0.9890E+00	0.9951E+00	0.1005E+01	0.1193E+01	0.2769E+00	0.9865E+00	0.1019E+01	0.9812E+00	0.1160E+01	0.4005E+00
0.9399E+00	0.9202E+00	0.1080E+01	0.1208E+01	0.2209E+00	0.9685E+00	0.1050E+01	0.9505E+00	0.1145E+01	0.4565E+00
0.9685E+00	0.9509E+00	0.1049E+01	0.1193E+01	0.2769E+00	0.9399E+00	0.1043E+01	0.9572E+00	0.1181E+01	0.3200E+00
0.9738E+00	0.9907E+00	0.1009E+01	0.1207E+01	0.2252E+00	0.9779E+00	0.1047E+01	0.9529E+00	0.1179E+01	0.3280E+00
0.9779E+00	0.9951E+00	0.1005E+01	0.1204E+01	0.2332E+00	0.9738E+00	0.1282E+01	0.7179E+00	0.1160E+01	0.4005E+00
0.9237E+00	0.1034E+01	0.9657E+00	0.1280E+01	-0.5079E-01	0.8463E+00	0.1199E+01	0.8013E+00	0.1200E+01	0.2486E+00
0.8463E+00	0.9509E+00	0.1049E+01	0.1321E+01	-0.2027E+00	0.9237E+00	0.7538E+00	0.6642E+00	0.8561E+00	0.4968E+00
0.7657E+00	0.7677E+00								

1 FREQUENCY CONSTRAINTS 173 TC 173 MOST CRITICAL CONSTRAINT= 0.4069898E-02
0.4070E-02

0 CONSTRAINTS OUT OF 0 CUTOFF POINT= 0.0

0 CONSTRAINTS OUT OF 0 CUTOFF POINT= 0.0

50 CONSTRAINTS OUT OF 172 CUTOFF POINT= 0.879735E+00

4	9	14	19	24	29	34	39	44	49
54	59	61	64	69	70	71	74	75	81
82	84	85	86	90	95	100	105	110	115
120	125	130	135	140	145	148	150	155	156
158	160	161	165	167	168	169	170	171	172

31 CONSTRAINTS OUT OF 50 RETAINED DUE TO VARIABLE LINKING

4	9	19	39	44	54	61	64	71	74
75	81	82	84	85	90	95	105	115	130
145	148	150	155	158	161	165	167	168	170
172									

1 CONSTRAINTS OUT OF 1 CUTOFF POINT= 0.900407E+00
173

0 CONSTRAINTS OUT OF 0 CUTOFF POINT= 0.900407E+00

AVAILABLE INTEGER ARRAY= 2500 OVERLAY ANALYS REQUIREMENT= 812

POSTURE TABLE

RETAINED	TOTAL	TYPE	MEMBER	NODE DIRECTION	L.C.	MODE	CONSTRAINT VALUES
STRESS/STRAIN CONSTRAINTS		MOST CRITICAL =	-0.202653E+00				
1	4	3	1		1	3	0.319969E+00
2	9	3	2		1	3	0.335487E+00
3	19	3	4		1	3	0.399856E+00
4	39	3	8		1	3	0.399880E+00
5	44	3	9		1	3	0.319997E+00
6	54	3	11		1	3	0.295887E+00
7	61	3	13		1	-2	0.676179E+00
8	64	3	13		1	3	0.421723E+00
9	71	3	15		1	-2	0.722825E+00
10	74	3	15		1	3	0.506687E+00
11	75	3	15		1	4	0.877862E+00
12	81	4	1		1	1	0.754393E+00
13	82	4	2		1	1	0.668771E+00
14	84	4	4		1	1	0.562814E+00
15	85	4	5		1	1	0.780285E+00
16	90	3	1		2	3	0.319966E+00
17	95	3	2		2	3	0.271844E+00
18	105	3	4		2	3	0.276867E+00
19	115	3	6		2	3	0.220887E+00
20	130	3	9		2	3	0.320004E+00
21	145	3	12		2	3	0.233213E+00
22	148	3	13		2	2	0.717949E+00
23	150	3	13		2	3	[illegible]

				1	3	0.399856E+00
4	39	3	8	1	3	0.399880E+00
5	44	3	9	1	3	0.319997E+00
6	54	3	11	1	3	0.295887E+00
7	61	3	13	1	-2	0.676179E+00
8	64	3	13	1	3	0.421723E+00
9	71	3	15	1	-2	0.722825E+00
10	74	3	15	1	3	0.506687E+00
11	75	3	15	1	4	0.877862E+00
12	81	4	1	1	1	0.754393E+00
13	82	4	2	1	1	0.668771E+00
14	84	4	4	1	1	0.562814E+00
15	85	4	5	1	1	0.780285E+00
16	90	3	1	2	3	0.319966E+00
17	95	3	2	2	3	0.271844E+00
18	105	3	4	2	3	0.276867E+00
19	115	3	6	2	3	0.220887E+00
20	130	3	9	2	3	0.320004E+00
21	145	3	12	2	3	0.233213E+00
22	148	3	13	2	2	0.717949E+00
23	150	3	13	2	3	0.400452E+00
24	155	3	14	2	3	-0.507920E-01
25	158	3	15	2	2	0.801324E+00
26	161	3	15	2	4	0.846270E+00
27	165	3	16	2	3	-0.202653E+00
28	167	4	1	2	1	0.753750E+00
29	168	4	2	2	1	0.664164E+00
30	170	4	4	2	1	0.496804E+00
31	172	4	6	2	1	0.767722E+00

FREQUENCY CONSTRAINTS MOST CRITICAL = 0.406990E-02

32	173				-1	0.406990E-02

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MODE STANDS FOR THE FOLLOWING
     NEGATIVE=LOWER BOUND   POSITIVE=UPPER BOUND
        FOR STRESS CONSTRAINT, (CODE+1)
            1 = VON MISES EQUIVALENT STRESS
            2 = LONGITUDINAL STRAIN
            3 = TRANSVERSE STRAIN
            4 = SHEAR STRAIN
            5 = FIRST EQUATION OF STRESS INTERACTION
            6 = SECOND EQUATION OF STRESS INTERACTION
            7 = TSAI-AZZI CRITERION
            FOR FREQUENCY CONSTRAINTS, ASSOCIATED MODE NUMBER
```

AVAILABLE REAL ARRAY = 7500 OVERLAY ANALYS REQUIREMENT= 1000

ANALYSIS TIME DATA

ASSEMBLE MASS/STIFFNESS MATRIX	0.985413E-01
ASSEMBLE LOAD VECTORS	0.519714E-01
DECOMPOSE STIFFNESS MATRIX	0.239563E-02
SOLUTION OF DISPLACEMENTS	0.271606E-02
FREQUENCY ANALYSIS	0.323944E-01
FLUTTER ANALYSIS	0.0
CONSTRAINT EVALUATION	0.160202E+00
POSTURE TABLE SET	0.601044E-01
SELECTIVE GRADIENT EVALUATION	0.486038E+00
GRAND TOTAL CPU TIME	0.975937E+00

END OVERLAY ANALYS

SCALING FACTOR 0.120265E+01 SCALED WEIGHT 0.519228E+05

SIDE CONSTRAINTS

RELATIVE MOVE LIMIT 0.2000E+00

VARIABLE NUMBER		LOWER BOUND	ACTUAL SIZE	UPPER BOUND	VARIABLE NUMBER		LOWER BOUND	ACTUAL SIZE	UPPER BOUND
DIS.	1	0.8000E-01	0.4000E+00	0.2000E+01	DIS.	2	0.6000E-01	0.3500E+00	0.1760E+01
DIS.	3	0.2000E-01	0.1000E+00	0.5100E+00	DIS.	4	0.2500E+00	0.1250E+01	0.2000E+01
DIS.	5	0.1500E+00	0.7500E+00	0.2000E+01	DIS.	6	0.5000E-01	0.2500E+00	0.1260E+01
DIS.	7	0.4000E-01	0.2000E+00	0.1010E+01	DIS.	8	0.2000E-01	0.1000E+00	0.5100E+00
DIS.	9	0.2000E-01	0.1000E+00	0.5100E+00		10	0.1200E+00	0.6000E+00	0.3000E+01
	11	0.1200E+00	0.6000E+00	0.3000E+01		12	0.1200E+00	0.6000E+00	0.3000E+01
	13	0.1200E+00	0.6000E+00	0.3000E+01					

MOST VIOLATED SIDE CONSTRAINT - DESIGN VARIABLE 4 CONSTRAINT VALUE [illegible]

SCALED WEIGHT 0.519228E+05

SIDE CONSTRAINTS

RELATIVE MOVE LIMIT 0.2000E+00

VARIABLE NUMBER	LOWER BOUND	ACTUAL SIZE	UPPER BOUND	VARIABLE NUMBER	LOWER BOUND	ACTUAL SIZE	UPPER BOUND
DIS. 1	0.8000E-01	0.4000E+00	0.2000E+01	DIS. 2	0.6000E-01	0.3500E+00	0.1760E+01
DIS. 3	0.2000E-01	0.1000E+00	0.5100E+00	DIS. 4	0.2500E+00	0.1250E+01	0.2000E+01
DIS. 5	0.1500E+00	0.7500E+00	0.2000E+01	DIS. 6	0.5000E-01	0.2500E+00	0.1260E+01
DIS. 7	0.4000E-01	0.2000E+00	0.1010E+01	DIS. 8	0.2000E-01	0.1000E+00	0.5100E+00
DIS. 9	0.2000E-01	0.1000E+00	0.5100E+00	10	0.1200E+00	0.6000E+00	0.3000E+01
11	0.1200E+00	0.6000E+00	0.3000E+01	12	0.1200E+00	0.6000E+00	0.3000E+01
13	0.1200E+00	0.6000E+00	0.3000E+01				

MOST VIOLATED SIDE CONSTRAINT - DESIGN VARIABLE 4 CONSTRAINT VALUE 0.6000E+00

ENTER OVERLAY PREDU1

AVAILABLE REAL ARRAY = 7500 OVERLAY PREDU1 REQUIREMENT= 4796
AVAILABLE INTEGER ARRAY= 2500 OVERLAY PREDU1 REQUIREMENT= 770

===== D U A L 1 O P T I M I Z E R =====

DUAL VARIABLES :

0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04
0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04
0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04
0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04

PHASE COM DUAL OBJ. WEIGHT ZMCD NACT NPLAN ICONJ NALFA NEWTON NDIS [illegible]

===== D U A L 1   O P T I M I Z E R =====

DUAL VARIABLES :

0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04
0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04
0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04
0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04	0.88794E+04

PHASE	ODM	DUAL OBJ.	WEIGHT	ZMOD	NACT	NPLAN	ICONJ	NALFA	NEWTON	NDIS	IDIS
1	1	-0.1720E+05	0.2313E+05	0.3473E+01	32	0	0	11	0	82	0
1	2	-0.1477E+05	0.2277E+05	0.3023E+01	31	0	0	14	0	3	0
1	3	-0.1098E+05	0.2248E+05	0.2882E+01	30	0	0	26	0	2	0
1	4	-0.9786E+04	0.2243E+05	0.2696E+01	29	0	0	22	0	0	0
1	5	-0.8654E+04	0.2211E+05	0.2536E+01	28	0	0	7	0	3	0
1	6	-0.7762E+04	0.2206E+05	0.2358E+01	27	0	0	25	0	0	0
1	7	-0.6301E+04	0.2183E+05	0.2179E+01	26	0	0	12	0	1	0
1	8	-0.6285E+04	0.2183E+05	0.2057E+01	25	0	0	28	0	0	0
1	9	-0.3566E+04	0.2134E+05	0.2031E+01	24	0	0	30	0	3	0
1	10	-0.3016E+04	0.2133E+05	0.1899E+01	23	0	0	31	0	0	0
1	11	-0.2625E+04	0.2132E+05	0.1736E+01	22	0	0	9	0	0	0
1	12	0.2447E+04	0.2074E+05	0.1564E+01	21	0	0	29	0	4	0
1	13	0.3767E+04	0.2075E+05	0.1432E+01	20	0	0	13	0	0	0
1	14	0.9601E+04	0.2086E+05	0.1412E+01	19	0	0	15	0	2	0
1	15	0.1006E+05	0.2086E+05	0.1302E+01	18	0	0	8	0	0	0
1	16	0.1289E+05	0.2085E+05	0.1210E+01	17	0	0	4	0	5	0
1	17	0.1290E+05	0.2085E+05	0.1091E+01	16	0	0	3	0	0	0
1	18	0.1562E+05	0.2083E+05	0.9739E+00	15	0	0	23	0	3	0
1	19	0.1864E+05	0.2089E+05	0.8832E+00	14	0	0	2	0	3	0
1	20	0.1977E+05	0.2088E+05	0.8085E+00	13	0	0	20	0	0	0
1	21	0.1977E+05	0.2088E+05	0.7424E+00	12	0	0	5	0	0	0
1	22	0.1977E+05	0.2088E+05	0.6699E+00	11	0	0	16	0	0	0
1	23	0.1977E+05	0.2088E+05	0.5886E+00	10	0	0	1	0	0	0
1	24	0.1993E+05	0.2093E+05	0.4941E+00	9	0	0	10	0	1	0
1	25	0.2062E+05	0.2105E+05	0.3871E+00	8	0	0	6	0	3	0
1	26	0.2166E+05	0.2154E+05	0.2588E+00	7	0	0	17	0	8	0
1	27	0.2232E+05	0.2167E+05	0.1773E+00	6	0	0	18	0	3	0
1	28	0.2287E+05	0.2240E+05	0.1331E+00	5	0	0	21	0	9	0
1	29	0.2319E+05	0.2304E+05	0.8177E-01	4	0	0	19	0	9	0
1	30	0.2326E+05	0.2293E+05	0.8710E-01	3	0	0	0	0	3	9
1	31	0.2338E+05	0.2413E+05	0.3076E-01	3	1	0	24	0	11	0
1	32	0.2341E+05	0.2354E+05	0.2632E-01	2	1	0	0	0	6	4
1	33	0.2341E+05	0.2354E+05	0.0	2	2	0	0	0	6	4

DUAL VARIABLES :

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.68341E+04	0.0	0.0	0.0	0.0	0.24692E+05

PHASE	ODM	DUAL OBJ.	WEIGHT	ZMOD	NACT	NPLAN	ICONJ	NALFA	NEWTON	NDIS	IDIS
2	1	0.2341E+05	0.2354E+05	0.2532E-01	2	1	0	0	0	1	9
2	2	0.2341E+05	0.2354E+05	0.0	2	2	0	0	0	1	9

NUMBER OF RESTARTS	2	MAXPH	=	10
TOTAL NUMBER OF O.D.M.	35	MAXODM	=	100
NUMBER OF NON-ZERO DUAL VARIABLES	2	NTCE	=	32
NUMBER OF DISCONTINUITY PLANES	2	NLDV	=	13
DUAL OBJECTIVE FUNCTION	0.234060E+05	EPSPH	=	0.100000E-04
NORM OF (PROJECTED) GRADIENT	0.0	EPSODM	=	0.100000E-03

DUAL VARIABLES :

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.68341E+04	0.0	0.0	0.0	0.0	0.24692E+05

ANALYSIS OF DUAL SOLUTION

NUMBER OF DISCONTINUITY PLANES 2

NUMBER OF POSSIBLE PRIMAL POINTS 4

WEIGHT OF UPPER BOUND SOLUTION 0.235435E+05 INFEASIBLE

```
NUMBER OF DISCONTINUITY PLANES          2                NLDV    =   13
DUAL OBJECTIVE FUNCTION                 0.234060E+05     EPSPH   =   0.100000E-04
NORM OF (PROJECTED) GRADIENT            0.0              EPSODM  =   0.100000E-03

   DUAL VARIABLES :
      0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
      0.0          0.0          0.68341E+04  0.0          0.0          0.0          0.0          0.24692E+05

ANALYSIS OF DUAL SOLUTION
-------------------------

NUMBER OF DISCONTINUITY PLANES          2
NUMBER OF POSSIBLE PRIMAL POINTS        4
WEIGHT OF UPPER BOUND SOLUTION          0.235435E+05     INFEASIBLE
MOST VIOLATED CONSTRAINT                32               VALUE   =   0.386053E-02

        PRIMAL VARIABLES
      0.22500E+00   0.17143E+00   0.20000E+00   0.47200E+00   0.50667E+00   0.20000E+00   0.33500E+01   0.18000E+01
      0.30000E+00   0.91339E+00   0.90757E+00   0.12504E+01   0.63760E+00

        CONSTRAINTS
     -0.31989E+00  -0.29248E+00  -0.43518E+00  -0.43528E+00  -0.31999E+00  -0.25984E+00  -0.89255E+00  -0.56579E+00
     -0.76513E+00  -0.33371E+00  -0.10150E+01  -0.69578E+00  -0.49557E+00  -0.78027E+00  -0.46765E+00  -0.31990E+00
     -0.14412E+00  -0.11014E+00  -0.62869E-01  -0.32001E+00  -0.92540E-01  -0.84791E+00  -0.46658E+00  -0.44490E-01
     -0.85364E+00  -0.88975E+00  -0.34064E-01  -0.69567E+00  -0.50304E+00  -0.67107E+00  -0.78161E+00   0.38605E-02

WEIGHT OF LOWER BOUND SOLUTION          0.233821E+05

        PRIMAL VARIABLES
      0.22500E+00   0.17143E+00   0.20000E+00   0.46400E+00   0.50667E+00   0.20000E+00   0.33500E+01   0.18000E+01
      0.20000E+00   0.91339E+00   0.90757E+00   0.12504E+01   0.63760E+00

        CONSTRAINTS
     -0.31988E+00  -0.28817E+00  -0.43398E+00  -0.43409E+00  -0.31999E+00  -0.25691E+00  -0.89527E+00  -0.57868E+00
     -0.76043E+00  -0.33308E+00  -0.10196E+01  -0.69177E+00  -0.49348E+00  -0.76374E+00  -0.46699E+00  -0.31990E+00
     -0.13932E+00  -0.10704E+00  -0.63235E-01  -0.32001E+00  -0.91815E-01  -0.81486E+00  -0.47699E+00  -0.16078E-01
     -0.83804E+00  -0.87175E+00   0.26137E-01  -0.69165E+00  -0.50109E+00  -0.66032E+00  -0.77469E+00  -0.62685E-02

WEIGHT OF FINAL DESIGN                  0.235435E+05     INFEASIBLE
MOST VIOLATED CONSTRAINT                32               VALUE   =   0.386053E-02
NUMBER OF PRIMAL VARIABLES FROM LOWER BOUND SOLUTION         0

        PRIMAL VARIABLES
      0.22500E+00   0.17143E+00   0.20000E+00   0.47200E+00   0.50667E+00   0.20000E+00   0.33500E+01   0.18000E+01
      0.30000E+00   0.91339E+00   0.90757E+00   0.12504E+01   0.63760E+00

        CONSTRAINTS
     -0.31989E+00  -0.29248E+00  -0.43518E+00  -0.43528E+00  -0.31999E+00  -0.25984E+00  -0.89255E+00  -0.56579E+00
     -0.76513E+00  -0.33371E+00  -0.10150E+01  -0.69578E+00  -0.49557E+00  -0.78027E+00  -0.46765E+00  -0.31990E+00
     -0.14412E+00  -0.11014E+00  -0.62869E-01  -0.32001E+00  -0.92539E-01  -0.84791E+00  -0.46658E+00  -0.44490E-01
     -0.85364E+00  -0.88975E+00  -0.34064E-01  -0.69567E+00  -0.50304E+00  -0.67107E+00  -0.78161E+00   0.38605E-02

                                                   END OVERLAY PREDU1


  RESPONSE FACTOR REDUCED TO    0.0

  TRUNCATION FACTORS MODIFIED AS FOLLOWS
    STRESS/STRAIN CONSTRAINT      0.150000E+00
    FREQUENCY CONSTRAINTS         0.120000E+00

    UPDATED SCALING FACTORS
        0.2250E+00  0.1714E+00  0.2000E+00  0.4720E+00  0.5067E+00  0.2000E+00  0.3350E+01  0.1800E+01  0.3000E+00  0.9134E+00
        0.9076E+00  0.1250E+01  0.6376E+00

    UPDATED WEIGHT COEFFICIENTS
        0.4842E+03  0.6456E+03  0.1076E+03  0.6346E+04  0.8175E+04  0.5378E+03  0.3602E+04  0.1935E+04  0.1613E+03  0.2338E+03
        0.4122E+03  0.4748E+03  0.4283E+03  0.0         0.4800E+05
```

```
RESPONSE FACTOR REDUCED TO    0.0

TRUNCATION FACTORS MODIFIED AS FOLLOWS
  STRESS/STRAIN CONSTRAINT     0.150000E+00
  FREQUENCY CONSTRAINTS        0.120000E+00

  UPDATED SCALING FACTORS
      0.2250E+00  0.1714E+00  0.2000E+00  0.4720E+00  0.5067E+00  0.2000E+00  0.3350E+01  0.1800E+01  0.3000E+00  0.9134E+00
      0.9076E+00  0.1250E+01  0.6376E+00

  UPDATED WEIGHT COEFFICIENTS
      0.4842E+03  0.6456E+03  0.1076E+03  0.6346E+04  0.8175E+04  0.5378E+03  0.3602E+04  0.1935E+04  0.1613E+03  0.2338E+03
      0.4122E+03  0.4748E+03  0.4283E+03  0.0         0.4800E+05
```

```
STAGE NO.  6   APPROXIMATE PROBLEM GENERATOR

  CURRENT MEMBER SIZE
    MEMBER TYPE NUMBER  3
        0.1000E-01  0.1000E-01  0.1000E-01  0.1000E-01  0.5600E+00  0.4600E+00  0.4600E+00  0.1000E-01  0.5600E+00  0.4600E+00
        0.4600E+00  0.1000E-01  0.5800E+00  0.1100E+00  0.1100E+00  0.1000E-01
    MEMBER TYPE NUMBER  4
        0.6823E+00  0.7736E+00  0.6715E+00  0.6715E+00  0.5700E+00  0.5700E+00
    MEMBER TYPE NUMBER  6
        0.6823E+00  0.7736E+00  0.6715E+00  0.6715E+00  0.5700E+00  0.5700E+00

  CURRENT WEIGHT DATA
    MEMBER TYPE NUMBER    3     WEIGHT =   0.205963E+05
    MEMBER TYPE NUMBER    4     WEIGHT =   0.193988E+04
         VARIABLE STRUCTURAL WEIGHT    0.225361E+05
         FIXED STRUCTURAL WEIGHT       0.0
              TOTAL STRUCTURAL WEIGHT       0.225361E+05
              NON-STRUCTURAL WEIGHTHT       0.480000E+05
                     TOTAL WEIGHT               0.705361E+05

    CONVERGENCE CHECK     STAGE NO.=    6        0.1077E-02     0.8010E-02   MUST BE LESS THAN   0.500000E-02
       OBJECTIVE FUNCTION OF THREE CONSECUTIVE STAGES ARE    0.227411E+05   0.225604E+05   0.225361E+05

                                              ENTER OVERLAY ANALYS

NEW AVAILABLE REAL ARRAY    =   7473

 AVAILABLE INTEGER ARRAY=   2500   OVERLAY ANALYS REQUIREMENT=    772

                                            POSTURE TABLE
```

RETAINED	TOTAL	TYPE	MEMBER	NODE DIRECTION	L.C.	MODE	CONSTRAINT VALUES
STRESS/STRAIN CONSTRAINTS		MOST CRITICAL =		0.742754E-01			
1	54	3	11		1	3	0.264776E+00
2	95	3	2		2	3	0.191498E+00
3	105	3	4		2	3	0.159115E+00
4	115	3	6		2	3	0.101879E+00
5	145	3	12		2	3	0.141490E+00
6	155	3	14		2	3	0.742754E-01
7	165	3	16		2	3	0.960189E-01
FREQUENCY CONSTRAINTS		MOST CRITICAL =		-0.498237E-02			
8	173					-1	-0.498237E-02

MODE STANDS FOR THE FOLLOWING

```
FREQUENCY CONSTRAINTS      MOST CRITICAL =  -0.498237E-02
        8         173                                                       -1        -0.498237E-02
----------------------------------------------------------------------------------------------------
      MODE STANDS FOR THE FOLLOWING
          NEGATIVE=LOWER BOUND    POSITIVE=UPPER BOUND
            FOR STRESS CONSTRAINT, (CODE+1)
               1 = VON MISES EQUIVALENT STRESS
               2 = LONGITUDINAL STRAIN
               3 = TRANSVERSE STRAIN
               4 = SHEAR STRAIN
               5 = FIRST EQUATION OF STRESS INTERACTION
               6 = SECOND EQUATION OF STRESS INTERACTION
               7 = TSAI-AZZI CRITERION
               FOR FREQUENCY CONSTRAINTS, ASSOCIATED MODE NUMBER

-----------------------------------------------------------------
AVAILABLE REAL ARRAY    =   7500   OVERLAY ANALYS REQUIREMENT=    976
-----------------------------------------------------------------


                                        END OVERLAY ANALYS

      SCALING FACTOR      0.100501E+01          SCALED WEIGHT       0.226490E+05

                                        SIDE CONSTRAINTS
                                        ----------------

RELATIVE MOVE LIMIT          0.8333E+00
```

VARIABLE NUMBER	LOWER BOUND	ACTUAL SIZE	UPPER BOUND	VARIABLE NUMBER	LOWER BOUND	ACTUAL SIZE	UPPER BOUND
DIS. 1	0.1000E-01	0.1000E-01	0.2000E-01	DIS. 2	0.1000E-01	0.1000E-01	0.2000E-01
DIS. 3	0.1000E-01	0.1000E-01	0.2000E-01	DIS. 4	0.4600E+00	0.5600E+00	0.6800E+00
DIS. 5	0.3800E+00	0.4600E+00	0.5600E+00	DIS. 6	0.1000E-01	0.1000E-01	0.2000E-01
DIS. 7	0.4800E+00	0.5800E+00	0.7000E+00	DIS. 8	0.9000E-01	0.1100E+00	0.1400E+00
DIS. 9	0.1000E-01	0.1000E-01	0.2000E-01	10	0.5686E+00	0.6823E+00	0.8188E+00
11	0.6447E+00	0.7736E+00	0.9283E+00	12	0.5596E+00	0.6715E+00	0.8058E+00
13	0.4750E+00	0.5700E+00	0.6840E+00				

```
MOST VIOLATED SIDE CONSTRAINT   -  DESIGN VARIABLE    9       CONSTRAINT VALUE    0.0
```



```
                                        ENTER OVERLAY PREDU1

-----------------------------------------------------------------
AVAILABLE REAL ARRAY    =   7500   OVERLAY PREDU1 REQUIREMENT=   3872
AVAILABLE INTEGER ARRAY=    2500   OVERLAY PREDU1 REQUIREMENT=    746
-----------------------------------------------------------------


                              ===== D U A L 1   O P T I M I Z E R =====
                                    ==============================

    DUAL VARIABLES :
          0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.29118E+05
```

PHASE	COM	DUAL OBJ.	WEIGHT	ZMCD	NACT	NPLAN	ICONJ	NALFA	NEWTON	NDIS	IDIS
1	1	0.2246E+05	0.2250E+05	0.1068E-01	1	0	0	0	0	2	5
1	2	0.2246E+05	0.2250E+05	0.0	1	1	0	0	0	2	5

```
    DUAL VARIABLES :
          0.0          0.0
```

===== D U A L 1   O P T I M I Z E R =====

DUAL VARIABLES :

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.29118E+05

PHASE	ODM	DUAL OBJ.	WEIGHT	ZMOD	NACT	NPLAN	ICONJ	NALFA	NEWTON	NDIS	IDIS
1	1	0.2246E+05	0.2250E+05	0.1068E-01	1	0	0	0	0	2	5
1	2	0.2246E+05	0.2250E+05	0.0	1	1	0	0	0	2	5

DUAL VARIABLES :

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.29830E+05

PHASE	ODM	DUAL OBJ.	WEIGHT	ZMOD	NACT	NPLAN	ICONJ	NALFA	NEWTON	NDIS	IDIS
2	1	0.2246E+05	0.2250E+05	0.0	1	1	0	0	0	2	5

NUMBER OF RESTARTS	2	MAXPH	=	10
TOTAL NUMBER OF O.D.M.	3	MAXODM	=	100
NUMBER OF NON-ZERO DUAL VARIABLES	1	NTCE	=	8
NUMBER OF DISCONTINUITY PLANES	1	NLDV	=	13
DUAL OBJECTIVE FUNCTION	0.224646E+05	EPSPH	=	0.100000E-04
NORM OF (PROJECTED) GRADIENT	0.0	EPSODM	=	0.100000E-03

DUAL VARIABLES :

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.29830E+05

ANALYSIS OF DUAL SOLUTION

NUMBER OF DISCONTINUITY PLANES 1

NUMBER OF POSSIBLE PRIMAL POINTS 2

WEIGHT OF UPPER BOUND SOLUTION 0.224957E+05 FEASIBLE

PRIMAL VARIABLES

0.10000E+01	0.10000E+01	0.10000E+01	0.10000E+01	0.10652E+01	0.10000E+01	0.82759E+00	0.81818E+00
0.10000E+01	0.10366E+01	0.10490E+01	0.99547E+00	0.10462E+01			

CONSTRAINTS

-0.26941E+00	-0.19952E+00	-0.16876E+00	-0.10666E+00	-0.14653E+00	-0.42562E-01	-0.48527E-01	-0.10435E-02

WEIGHT OF LOWER BOUND SOLUTION 0.222806E+05

PRIMAL VARIABLES

0.10000E+01	0.10000E+01	0.10000E+01	0.10000E+01	0.10435E+01	0.10000E+01	0.82759E+00	0.81818E+00
0.10000E+01	0.10366E+01	0.10490E+01	0.99547E+00	0.10462E+01			

CONSTRAINTS

-0.26770E+00	-0.19920E+00	-0.16822E+00	-0.10368E+00	-0.14372E+00	-0.40227E-01	-0.48694E-01	0.61680E-02

WEIGHT OF FINAL DESIGN 0.224957E+05 FEASIBLE

NUMBER OF PRIMAL VARIABLES FROM LOWER BOUND SOLUTION 0

PRIMAL VARIABLES

0.10000E+01	0.10000E+01	0.10000E+01	0.10000E+01	0.10652E+01	0.10000E+01	0.82759E+00	0.81818E+00
0.10000E+01	0.10366E+01	0.10490E+01	0.99547E+00	0.10462E+01			

CONSTRAINTS

-0.26941E+00	-0.19952E+00	-0.16876E+00	-0.10666E+00	-0.14653E+00	-0.42562E-01	-0.48527E-01	-0.10435E-02

END OVERLAY PREDL1

```
RESPONSE FACTOR REDUCED TO    0.0

TRUNCATICN FACTORS MODIFIED AS FOLLOWS
    STRESS/STRAIN CCNSTRAINT     0.900000E+00
    FREQUENCY CCNSTPAINTS        0.298598E+00

    UPDATED SCALING FACTORS
        0.2500E-01  0.2857E-01  0.1000E+00  0.4480E+00  0.6533E+00  0.4000E-01  0.2400E+01  0.9000E+00  0.1000E+00  0.1179E+01
        0.1352E+01  0.1114E+01  0.9939E+00

    UPDATED WEIGHT COEFFICIENTS
        0.5380E+02  0.1076E+03  0.5380E+02  0.6023E+04  0.1054E+05  0.1076E+03  0.2580E+04  0.9677E+03  0.5376E+02  0.3017E+03
        0.6143E+03  0.4231E+03  0.6677E+03  0.0         0.4800E+05
```

STAGE NO. 7 APPROXIMATE PROBLEM GENERATOR

CURRENT MEMBER SIZE

```
MEMBER TYPE NUMBER  3
    0.1000E-01  0.1000E-01  0.1000E-01  0.1000E-01  0.5600E+00  0.4900E+00  0.4900E+00  0.1000E-01  0.5600E+00  0.4900E+00
    0.4900E+00  0.1000E-01  0.4800E+00  0.9000E-01  0.9000E-01  0.1000E-01
MEMBER TYPE NUMBER  4
    0.7C73E+00  0.8115E+00  0.6685E+00  0.6685E+00  0.5963E+00  0.5963E+00
MEMBER TYPE NUMBER  6
    0.7073E+00  0.8115E+00  0.6685E+00  0.6685E+00  0.5963E+00  0.5963E+00
```

CURRENT WEIGHT DATA

```
MEMBER TYPE NUMBER     3     WEIGHT =   0.204890E+05
MEMBER TYPE NUMBER     4     WEIGHT =   0.200677E+04
     VARIABLE STRUCTURAL WEIGHT    0.224957E+05
     FIXED STRUCTURAL WEIGHT       0.0
          TOTAL STRUCTURAL WEIGHT      0.224957E+05
          NON-STRUCTURAL WEIGHTHT      0.480000E+05
                   TOTAL WEIGHT             0.704957E+05

CONVERGENCE CHECK      STAGE NO.=    7      0.1796E-02     0.1077E-02   MUST BE LESS THAN   0.500000E-02
   OBJECTIVE FUNCTION OF THREE CONSECUTIVE STAGES ARE    0.225604E+05    0.225361E+05    0.224957E+05
```

ENTER OVERLAY ANALYS

NODAL DISPLACEMENTS

NODE	X	Y	Z	NODE	X	Y	Z
LOAD CONDITION 1							
1	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	4	-0.14310E+00	0.42576E-01	0.38610E+01
5	-0.40865E+00	0.19068E+00	0.15345E+02	6	-0.76908E+00	0.52852E+00	0.68358E+02
LOAD CONDITION 2							
1	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	4	0.14310E+00	-0.42576E-01	-0.38610E+01

NODAL DISPLACEMENTS

NODE	X	Y	Z	NODE	X	Y	Z
LOAD CONDITION 1							
1	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	4	-0.14310E+00	0.42576E-01	0.38610E+01
5	-0.40865E+00	0.19068E+00	0.15345E+02	6	-0.76908E+00	0.52852E+00	0.68358E+02
LOAD CONDITION 2							
1	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	4	0.14310E+00	-0.42576E-01	-0.38610E+01
5	0.40865E+00	-0.19068E+00	-0.15345E+02	6	0.76908E+00	-0.52852E+00	-0.68358E+02

NODAL DISPLACEMENTS

NODE	X	Y	Z	NODE	X	Y	Z
LOAD CONDITION 1							
1	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	4	0.29981E-01	-0.21788E+00	-0.55807E-02
5	-0.97583E-01	0.12948E+00	-0.34034E-02	6	-0.98203E-01	0.26211E-01	-0.23360E-02
LOAD CONDITION 2							
1	0.0	0.0	0.0	2	0.0	0.0	0.0

NODAL DISPLACEMENTS

NODE	X	Y	Z	NODE	X	Y	Z
LOAD CONDITION 1							
1	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	4	0.29981E-01	-0.21788E+00	-0.55807E-02
5	-0.97583E-01	0.12948E+00	-0.34034E-02	6	-0.98203E-01	0.26211E-01	-0.23360E-02
LOAD CONDITION 2							
1	0.0	0.0	0.0	2	0.0	0.0	0.0
3	0.0	0.0	0.0	4	0.29981E-01	-0.21788E+00	-0.55807E-02
5	-0.97583E-01	0.12948E+00	-0.34034E-02	6	-0.98203E-01	0.26211E-01	-0.23360E-02

NEW AVAILABLE REAL ARRAY = 7473

EIGEN VECTORS SCALED BY MAX. COMPONENTS
VECTOR NO.= 1 FREQUENCY= 0.100502E+01 C/S
-0.1581E-02 0.5819E-03 0.4175E-01 -0.5727E-02 0.2836E-02 0.2085E+00 -0.1181E-01 0.8035E-02 0.1000E+01
VECTOR NO.= 2 FREQUENCY= 0.395797E+01 C/S
-0.1471E-01 0.2455E-02 0.4279E+00 -0.1342E-01 0.8765E-02 0.1000E+01 0.4540E-01 0.1912E-02 -0.5979E+00
VECTOR NO.= 3 FREQUENCY= 0.543532E+01 C/S
-0.3510E-01 -0.2519E-03 0.1000E+01 0.5961E-02 -0.3440E-01 -0.5307E+00 -0.1697E-01 -0.6252E-01 0.3832E-01

** EIGEN ANALYSIS CONVERGED IN 2 ITERATIONS **

EIGEN VALUES
0.3988E+02 0.6185E+03 0.1166E+04

EIGEN VECTORS SCALED BY UMU
VECTOR NO.= 1 FREQUENCY= 0.100502E+01 C/S
-0.2418E-03 0.8897E-04 0.6384E-02 -0.8756E-03 0.4336E-03 0.3188E-01 -0.1805E-02 0.1229E-02 0.1529E+00

MTYP	M	LC	S-COMBINED	SX	SY	SXY	SX-THERM	SY-THERM	SXY-THERM
3	1	1		-0.6401E-03	0.8129E-07	0.1183E-03			
3	1	1		-0.6068E-03	0.3200E-02	0.6624E-03	0.3330E-04	0.3200E-02	0.5441E-03
3	2	1		-0.3794E-03	-0.2606E-03	-0.6401E-03			
3	2	1		-0.6556E-03	0.3249E-02	-0.5647E-03	-0.2762E-03	0.3510E-02	0.7538E-04
3	3	1		-0.2607E-03	-0.3793E-03	0.6401E-03			
3	3	1		0.7147E-05	0.2586E-02	0.5649E-03	0.2679E-03	0.2966E-02	-0.7521E-04
3	4	1		-0.6464E-11	-0.6400E-03	-0.1191E-03			
3	4	1		-0.4200E-04	0.2636E-02	-0.6631E-03	-0.4200E-04	0.3276E-02	-0.5440E-03
3	5	1		-0.6401E-03	-0.3495E-03	-0.1377E-02			
3	5	1		-0.6068E-03	0.2127E-02	-0.1098E-02	0.3330E-04	0.2476E-02	0.2787E-03
3	6	1		0.1935E-03	-0.1183E-02	-0.2911E-03			
3	6	1		-0.3119E-03	0.1832E-02	0.5080E-03	-0.5054E-03	0.3015E-02	0.7991E-03
3	7	1		-0.1183E-02	0.1937E-03	0.2900E-03			
3	7	1		-0.1410E-02	0.2930E-02	-0.5089E-03	-0.2267E-03	0.2736E-02	-0.7989E-03
3	8	1		-0.3496E-03	-0.6401E-03	0.1377E-02			
3	8	1		-0.1115E-02	0.2635E-02	0.1098E-02	-0.7657E-03	0.3275E-02	-0.2788E-03
3	9	1		-0.1055E-02	0.3216E-07	-0.1451E-02			
3	9	1		-0.1341E-02	0.3200E-02	-0.1774E-02	-0.2859E-03	0.3200E-02	-0.3234E-03
3	10	1		0.1982E-03	-0.1253E-02	-0.1055E-02			
3	10	1		0.1960E-03	0.1663E-02	-0.1298E-02	-0.2245E-05	0.2916E-02	-0.2438E-03
3	11	1		-0.1253E-02	0.1979E-03	0.1056E-02			
3	11	1		-0.1579E-02	0.3438E-02	0.1300E-02	-0.3256E-03	0.3240E-02	0.2441E-03
3	12	1		-0.2041E-08	-0.1055E-02	0.1451E-02			
3	12	1		-0.4200E-04	0.1901E-02	0.1775E-02	-0.4200E-04	0.2956E-02	0.3234E-03
3	13	1		-0.1280E-02	-0.3496E-03	-0.1693E-02			
3	13	1		-0.1323E-02	0.2127E-02	-0.1701E-02	-0.4356E-04	0.2476E-02	-0.7605E-05
3	14	1		0.3203E-04	-0.1661E-02	-0.9302E-03			
3	14	1		-0.3688E-03	0.1172E-02	-0.2081E-03	-0.4008E-03	0.2834E-02	0.7221E-03
3	15	1		-0.1661E-02	0.3203E-04	0.9302E-03			
3	15	1		-0.2070E-02	0.2873E-02	0.2081E-03	-0.4084E-03	0.2841E-02	-0.7221E-03
3	16	1		-0.3496E-03	-0.1280E-02	0.1693E-02			
3	16	1		-0.1115E-02	0.1919E-02	0.1701E-02	-0.7657E-03	0.3198E-02	0.7596E-05
4	1	1	0.323892E+05	-0.5060E+04	0.0	0.1847E+05			
6	1	1	0.3300[illegible]E+05	[illegible]					

3	8	1		-0.1115E-02	0.2635E-02	0.1098E-02	-0.7657E-03	0.3275E-02	-0.2788E-03
3	9	1		-0.1055E-02	0.3216E-07	-0.1451E-02			
3	9	1		-0.1341E-02	0.3200E-02	-0.1774E-02	-0.2859E-03	0.3200E-02	-0.3234E-03
3	10	1		0.1982E-03	-0.1253E-02	-0.1055E-02			
3	10	1		0.1960E-03	0.1663E-02	-0.1298E-02	-0.2245E-05	0.2916E-02	-0.2438E-03
3	11	1		-0.1253E-02	0.1979E-03	0.1056E-02			
3	11	1		-0.1579E-02	0.3438E-02	0.1300E-02	-0.3256E-03	0.3240E-02	0.2441E-03
3	12	1		-0.2041E-08	-0.1055E-02	0.1451E-02			
3	12	1		-0.4200E-04	0.1901E-02	0.1775E-02	-0.4200E-04	0.2956E-02	0.3234E-03
3	13	1		-0.1280E-02	-0.3496E-03	-0.1693E-02			
3	13	1		-0.1323E-02	0.2127E-02	-0.1701E-02	-0.4356E-04	0.2476E-02	-0.7605E-05
3	14	1		0.3203E-04	-0.1661E-02	-0.9302E-03			
3	14	1		-0.3688E-03	0.1172E-02	-0.2081E-03	-0.4008E-03	0.2834E-02	0.7221E-03
3	15	1		-0.1661E-02	0.3203E-04	0.9302E-03			
3	15	1		-0.2070E-02	0.2873E-02	0.2081E-03	-0.4084E-03	0.2841E-02	-0.7221E-03
3	16	1		-0.3496E-03	-0.1280E-02	0.1693E-02			
3	16	1		-0.1115E-02	0.1919E-02	0.1701E-02	-0.7657E-03	0.3198E-02	0.7596E-05
4	1	1	0.323892E+05	-0.5060E+04	0.0	0.1847E+05			
6	1	1	0.330065E+05	-0.9355E+04	-0.5367E+04	0.1847E+05	-0.4294E+04	-0.5367E+04	0.0
4	2	1	0.398012E+05	-0.5867E+04	0.0	0.2273E+05			
6	2	1	0.402673E+05	0.7328E+04	0.9274E+04	0.2273E+05	0.1320E+05	0.9274E+04	0.0
4	3	1	0.167683E+05	-0.1675E+05	0.0	-0.3901E+03			
6	3	1	0.138219E+05	-0.9761E+04	0.6034E+04	-0.3901E+03	0.6993E+04	0.6034E+04	0.0
4	4	1	0.432547E+05	-0.1478E+05	0.0	0.2347E+05			
6	4	1	0.411189E+05	-0.5079E+04	0.1799E+04	0.2347E+05	0.9698E+04	0.1799E+04	0.0
4	5	1	0.418502E+05	-0.3263E+04	0.0	-0.2409E+05			
6	5	1	0.431735E+05	0.1281E+05	0.6646E+04	-0.2409E+05	0.1607E+05	0.6646E+04	0.0
4	6	1	0.213741E+05	-0.2032E+05	0.0	0.3833E+04			
6	6	1	0.189675E+05	-0.1927E+05	-0.3529E+04	0.3833E+04	0.1050E+04	-0.3529E+04	0.0
3	1	2		0.6401E-03	-0.8129E-07	-0.1183E-03			
3	1	2		0.6734E-03	0.3200E-02	0.4258E-03	0.3330E-04	0.3200E-02	0.5441E-03
3	2	2		0.3794E-03	0.2606E-03	0.6401E-03			
3	2	2		0.1032E-03	0.3770E-02	0.7155E-03	-0.2762E-03	0.3510E-02	0.7538E-04
3	3	2		0.2607E-03	0.3793E-03	-0.6401E-03			
3	3	2		0.5286E-03	0.3345E-02	-0.7154E-03	0.2679E-03	0.2966E-02	-0.7521E-04
3	4	2		0.6464E-11	0.6400E-03	0.1191E-03			
3	4	2		-0.4200E-04	0.3916E-02	-0.4248E-03	-0.4200E-04	0.3276E-02	-0.5440E-03
3	5	2		0.6401E-03	0.3495E-03	0.1377E-02			
3	5	2		0.6734E-03	0.2826E-02	0.1656E-02	0.3330E-04	0.2476E-02	0.2787E-03
3	6	2		-0.1935E-03	0.1183E-02	0.2911E-03			
3	6	2		-0.6989E-03	0.4198E-02	0.1090E-02	-0.5054E-03	0.3015E-02	0.7991E-03
3	7	2		0.1183E-02	-0.1937E-03	-0.2900E-03			
3	7	2		0.9566E-03	0.2543E-02	-0.1089E-02	-0.2267E-03	0.2736E-02	-0.7989E-03
3	8	2		0.3496E-03	0.6401E-03	-0.1377E-02			
3	8	2		-0.4161E-03	0.3915E-02	-0.1656E-02	-0.7657E-03	0.3275E-02	-0.2788E-03
3	9	2		0.1055E-02	-0.3216E-07	0.1451E-02			
3	9	2		0.7691E-03	0.3200E-02	0.1128E-02	-0.2859E-03	0.3200E-02	-0.3234E-03
3	10	2		-0.1982E-03	0.1253E-02	0.1055E-02			
3	10	2		-0.2004E-03	0.4170E-02	0.8108E-03	-0.2245E-05	0.2916E-02	-0.2438E-03
3	11	2		0.1253E-02	-0.1979E-03	-0.1056E-02			
3	11	2		0.9273E-03	0.3042E-02	-0.8115E-03	-0.3256E-03	0.3240E-02	0.2441E-03
3	12	2		0.2041E-08	0.1055E-02	-0.1451E-02			
3	12	2		-0.4200E-04	0.4011E-02	-0.1128E-02	-0.4200E-04	0.2956E-02	0.3234E-03
3	13	2		0.1280E-02	0.3496E-03	0.1693E-02			
3	13	2		0.1236E-02	0.2826E-02	0.1686E-02	-0.4356E-04	0.2476E-02	-0.7605E-05
3	14	2		-0.3203E-04	0.1661E-02	0.9302E-03			
3	14	2		-0.4328E-03	0.4495E-02	0.1652E-02	-0.4008E-03	0.2834E-02	0.7221E-03
3	15	2		0.1661E-02	-0.3203E-04	-0.9302E-03			
3	15	2		0.1253E-02	0.2809E-02	-0.1652E-02	-0.4084E-03	0.2841E-02	-0.7221E-03
3	16	2		0.3496E-03	0.1280E-02	-0.1693E-02			
3	16	2		-0.4161E-03	0.4478E-02	-0.1686E-02	-0.7657E-03	0.3198E-02	0.7596E-05
4	1	2	0.323892E+05	0.5060E+04	0.0	-0.1847E+05			
6	1	2	0.325109E+05	0.7659E+03	-0.5367E+04	-0.1847E+05	-0.4294E+04	-0.5367E+04	0.0
4	2	2	0.398012E+05	0.5867E+04	0.0	-0.2273E+05			
6	2	2	0.426886E+05	0.1906E+05	0.9274E+04	-0.2273E+05	0.1320E+05	0.9274E+04	0.0
4	3	2	0.167683E+05	0.1675E+05	0.0	0.3901E+03			
6	3	2	0.213901E+05	0.2375E+05	0.6034E+04	0.3901E+03	0.6993E+04	0.6034E+04	0.0
4	4	2	0.432547E+05	0.1478E+05	0.0	-0.2347E+05			
6	4	2	0.470199E+05	0.2448E+05	0.1799E+04	-0.2347E+05	0.9698E+04	0.1799E+04	0.0
4	5	2	0.418502E+05	0.3263E+04	0.0	0.2409E+05			
6	5	2	0.450599E+05	0.1934E+05	0.6646E+04	0.2409E+05	0.1607E+05	0.6646E+04	0.0
4	6	2	0.213741E+05	0.2032E+05	0.0	-0.3833E+04			
6	6	2	0.242581E+05	0.2137E+05	-0.3529E+04	-0.3833E+04	0.1050E+04	-0.3529E+04	0.0

172 STRESS/STRAIN CONSTRAINTS 1 TC 172 MOST CRITICAL CONSTRAINT= 0.4482635E-01

0.9292E+00	0.1071E+01	0.1181E+01	0.3199E+00	0.9641E+00	0.9235E+00	0.1076E+01	0.1184E+01	0.3095E+00	0.9694E+00
0.1001E+01	0.9992E+00	0.1147E+01	0.4504E+00	0.9694E+00	0.9951E+00	0.1005E+01	0.1149E+01	0.4399E+00	0.9641E+00
0.9292E+00	0.1071E+01	0.1121E+01	0.5481E+00	0.9405E+00	0.9636E+00	0.1036E+01	0.1104E+01	0.6107E+00	0.9725E+00
0.8355E+00	0.1164E+01	0.1166E+01	0.3774E+00	0.9724E+00	0.8699E+00	0.1130E+01	0.1149E+01	0.4400E+00	0.9405E+00
0.8435E+00	0.1156E+01	0.1181E+01	0.3200E+00	0.9039E+00	0.1023E+01	0.9771E+00	0.1094E+01	0.6466E+00	0.9297E+00
0.8158E+00	0.1184E+01	0.1195E+01	0.2695E+00	0.9296E+00	0.9951E+00	0.1005E+01	0.1108E+01	0.5960E+00	0.9039E+00
0.8456E+00	0.1154E+01	0.1121E+01	0.5481E+00	0.9079E+00	0.9570E+00	0.1043E+01	0.1066E+01	0.7509E+00	0.9887E+00
0.7585E+00	0.1241E+01	0.1163E+01	0.3894E+00	0.9887E+00	0.8699E+00	0.1130E+01	0.1109E+01	0.5923E+00	0.9079E+00
0.7359E+00	0.6779E+00	0.8394E+00	0.6710E+00	0.6546E+00	0.8483E+00	0.1079E+01	0.9214E+00	0.1181E+01	0.3199E+00
0.9769E+00	0.1012E+01	0.9880E+00	0.1214E+01	0.1988E+00	0.9612E+00	0.1062E+01	0.9383E+00	0.1190E+01	0.2892E+00
0.9613E+00	0.9951E+00	0.1005E+01	0.1222E+01	0.1679E+00	0.9770E+00	0.1079E+01	0.9214E+00	0.1160E+01	0.3995E+00
0.9103E+00	0.9185E+00	0.1082E+01	0.1238E+01	0.1079E+00	0.9409E+00	0.1112E+01	0.8884E+00	0.1144E+01	0.4597E+00
0.9410E+00	0.9515E+00	0.1049E+01	0.1222E+01	0.1680E+00	0.9103E+00	0.1090E+01	0.9103E+00	0.1181E+01	0.3200E+00

```
  6    4    2        0.470199E+05          0.2448E+05  0.1799E+04 -0.2347E+05       0.9698E+04  0.1799E+04  0.0
  4    5    2        0.418502E+05          0.3263E+04  0.0          0.2409E+05
  6    5    2        0.450599E+05          0.1934E+05  0.6646E+04  0.2409E+05       0.1607E+05  0.6646E+04  0.0
  4    6    2        0.213741E+05          0.2032E+05  0.0         -0.3833E+04
  6    6    2        0.242581E+05          0.2137E+05 -0.3529E+04 -0.3833E+04       0.1050E+04 -0.3529E+04  0.0

172  STRESS/STRAIN CONSTRAINTS                  1   TC 172    MOST CRITICAL CONSTRAINT=  0.4482635E-01
  0.9292E+00  0.1071E+01  0.1181E+01  0.3199E+00  0.9641E+00  0.9235E+00  0.1076E+01  0.1184E+01  0.3095E+00  0.9694E+00
  0.1001E+01  0.9792E+00  0.1147E+01  0.4504E+00  0.9694E+00  0.9951E+00  0.1005E+01  0.1149E+01  0.4399E+00  0.9641E+00
  0.9292E+00  0.1071E+01  0.1121E+01  0.5481E+00  0.9405E+00  0.9636E+00  0.1036E+01  0.1104E+01  0.6107E+00  0.9725E+00
  0.8355E+00  0.1164E+01  0.1166E+01  0.3774E+00  0.9724E+00  0.8699E+00  0.1130E+01  0.1149E+01  0.4400E+00  0.9405E+00
  0.8435E+00  0.1156E+01  0.1181E+01  0.3200E+00  0.9039E+00  0.1023E+01  0.9771E+00  0.1094E+01  0.6466E+00  0.9297E+00
  0.8158E+00  0.1184E+01  0.1195E+01  0.2695E+00  0.9296E+00  0.9951E+00  0.1005E+01  0.1108E+01  0.5960E+00  0.9039E+00
  0.8456E+00  0.1154E+01  0.1121E+01  0.5481E+00  0.9079E+00  0.9570E+00  0.1043E+01  0.1066E+01  0.7509E+00  0.9887E+00
  0.7585E+00  0.1241E+01  0.1163E+01  0.3894E+00  0.9887E+00  0.8699E+00  0.1130E+01  0.1109E+01  0.5923E+00  0.9079E+00
  0.7359E+00  0.6779E+00  0.8894E+00  0.6710E+00  0.6546E+00  0.8483E+00  0.1079E+01  0.9214E+00  0.1181E+01  0.3199E+00
  0.9769E+00  0.1012E+01  0.9880E+00  0.1214E+01  0.1988E+00  0.9612E+00  0.1062E+01  0.9383E+00  0.1190E+01  0.2892E+00
  0.9613E+00  0.9951E+00  0.1005E+01  0.1222E+01  0.1679E+00  0.9770E+00  0.1079E+01  0.9214E+00  0.1160E+01  0.3995E+00
  0.9103E+00  0.9185E+00  0.1082E+01  0.1238E+01  0.1079E+00  0.9409E+00  0.1112E+01  0.8884E+00  0.1144E+01  0.4597E+00
  0.9410E+00  0.9515E+00  0.1049E+01  0.1222E+01  0.1680E+00  0.9103E+00  0.1090E+01  0.9103E+00  0.1181E+01  0.3200E+00
  0.9389E+00  0.9766E+00  0.1023E+01  0.1236E+01  0.1140E+00  0.9561E+00  0.1108E+01  0.8918E+00  0.1172E+01  0.3536E+00
  0.9560E+00  0.9951E+00  0.1005E+01  0.1227E+01  0.1476E+00  0.9389E+00  0.1144E+01  0.8558E+00  0.1160E+01  0.3995E+00
  0.9087E+00  0.9495E+00  0.1050E+01  0.1255E+01  0.4483E-01  0.9105E+00  0.1146E+01  0.8538E+00  0.1159E+01  0.4031E+00
  0.9105E+00  0.9515E+00  0.1049E+01  0.1254E+01  0.4839E-01  0.9087E+00  0.7399E+00  0.6585E+00  0.8289E+00  0.6238E+00
  0.6395E+00  0.8059E+00

  1  FREQUENCY CONSTRAINTS                    173   TO 173    MOST CRITICAL CONSTRAINT= -0.3106689E-02
 -0.3107E-02

      0    CONSTRAINTS OUT OF    0      CUTOFF POINT=    0.0

      0    CONSTRAINTS OUT OF    0      CUTOFF POINT=    0.0

      4    CONSTRAINTS OUT OF  172      CUTOFF POINT=    0.140344E+00
           115          135          155          165

      3    CONSTRAINTS OUT OF    4    RETAINED DUE TO VARIABLE LINKING
           115          155          165

      1    CONSTRAINTS OUT OF    1      CUTOFF POINT=    0.700475E+00
           173

      0    CONSTRAINTS OUT OF    0      CUTOFF POINT=    0.700475E+00

 ------------------------------------------------------------------------
  AVAILABLE INTEGER ARRAY=   2500   OVERLAY ANALYS REQUIREMENT=     766
 ------------------------------------------------------------------------

                                              POSTURE TABLE
                                              -------------

         RETAINED      TOTAL       TYPE    MEMBER      NODE DIRECTION       L.C.       MODE   CONSTRAINT VALUES
        -------------------------------------------------------------------------------------------------------
        STRESS/STRAIN CONSTRAINTS      MOST CRITICAL =    0.448264E-01
              1          115         3        6                               2          3        0.107891E+00
              2          155         3       14                               2          3        0.448264E-01
              3          165         3       16                               2          3        0.483855E-01
        FREQUENCY CONSTRAINTS       MOST CRITICAL  =  -0.310669E-02
              4          173                                                            -1       -0.310669E-02
        -------------------------------------------------------------------------------------------------------
          MODE STANDS FOR THE FOLLOWING
              NEGATIVE=LOWER BOUND    POSITIVE=UPPER BOUND
                FOR STRESS CONSTRAINT, (CODE+1)
                    1 = VON MISES EQUIVALENT STRESS
                    2 = LONGITUDINAL STRAIN
                    3 = TRANSVERSE STRAIN
                    4 = SHEAR STRAIN
                    5 = FIRST EQUATION OF STRESS INTERACTION
                    6 = SECOND EQUATION OF STRESS INTERACTION
                    7 = TSAI-AZZI CRITERION
                    FOR FREQUENCY CONSTRAINTS, ASSOCIATED MODE NUMBER

 ------------------------------------------------------------------------
  AVAILABLE REAL ARRAY   =   7500   OVERLAY ANALYS REQUIREMENT=     972
 ------------------------------------------------------------------------

  ANALYSIS TIME DATA
    ASSEMBLE MASS/STIFFNESS MATRIX     0.647018E+00
    ASSEMBLE LOAD VECTORS              0.552063E-01
    DECOMPOSE STIFFNESS MATRIX         0.239563E-02
    SOLUTION OF DISPLACEMENTS          0.270081E-02
    FREQUENCY ANALYSIS                 0.335541E-01
    FLUTTER ANALYSIS                   0.0
    CONSTRAINT EVALUATION              0.154373E+00
```

```
3 = TRANSVERSE STRAIN
4 = SHEAR STRAIN
5 = FIRST EQUATION OF STRESS INTERACTION
6 = SECOND EQUATION OF STRESS INTERACTION
7 = TSAI-AZZI CRITERION
FOR FREQUENCY CONSTRAINTS, ASSOCIATED MODE NUMBER

-------------------------------------------------------------------------
AVAILABLE REAL ARRAY   =   7500   OVERLAY ANALYS REQUIREMENT=     972
-------------------------------------------------------------------------

ANALYSIS TIME DATA
  ASSEMBLE MASS/STIFFNESS MATRIX    0.647018E+00
  ASSEMBLE LOAD VECTORS             0.552063E-01
  DECOMPOSE STIFFNESS MATRIX        0.239563E-02
  SOLUTION OF DISPLACEMENTS         0.270081E-02
  FREQUENCY ANALYSIS                0.335541E-01
  FLUTTER ANALYSIS                  0.0
  CONSTRAINT EVALUATION             0.154373E+00
  POSTURE TABLE SET                 0.192719E-01
  SELECTIVE GRADIENT EVALUATION     0.342300E+00
-------------------------------------------------
     GRAND TOTAL CPU TIME           0.782822E+00

                                                  END OVERLAY ANALYS
     DIMINISHING RETURN OF THREE CONSECUTIVE STAGES


DESIGN TIME STATISTICS
 TOTAL                         7.4834
   INITIAL PREPARATION          0.0502
   DESIGN PHASE                 7.4333
     ANALYSIS TOTAL              5.4043
     OPTIMIZER TOTAL             0.5690

                                                  END OVERLAY DESIGN

MAIN PROGRAM TIME STATISTICS
```

```
DESIGN TIME STATISTICS
 TOTAL                              7.4834
   INITIAL PREPARATION               0.0502
   DESIGN PHASE                      7.4333
     ANALYSIS TOTAL                    5.4043
     OPTIMIZER TOTAL                   0.5690
```

END OVERLAY DESIGN

```
MAIN PROGRAM TIME STATISTICS
  PRE-PROCESSOR                        0.6258
  DESIGN PHASE                         7.4886
 ------------------------------------------------
    GRAND TOTAL                          8.1144
```

ENTER OVERLAY PREP00

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16. Abstract
This report serves as a user's guide for the ACCESS-3 computer program. ACCESS-3 is a research oriented program which combines dual methods and a collection of approximation concepts to achieve excellent efficiency in structural synthesis. The finite element method is used for structural analysis and dual algorithms of mathematical programming are applied in the design optimization procedure.

The ACCESS-3 program retains all of the ACCESS-2 capabilities and the data preparation formats are fully compatible. The following new features have been added in the program:

- four distinct optimizer options:
  - interior point penalty function method (NEWSUMT)
  - second order primal projection method (PRIMAL2)
  - second order Newton-type dual method (DUAL2)
  - first order gradient projection-type dual method (DUAL1)
- pure discrete and mixed continuous-discrete design variable capability
- zero order approximation of the stress constraints.

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