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OPTIMAL AIRFRAME SYNTHESIS
FOR GUST LOADS

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Introductory Remarks

The application of mathematical nonlinear programming algorithms has enjoyed considerable success in the automated structural synthesis environment. A sizeable majority of research pertaining to optimum structural design has primarily focussed on statically loaded structures. The addition of dynamic loading in the form of harmonic excitation (Ref. 1) or random loads (Ref. 2) to the structure introduces significant new problems. Since all aerospace vehicles operate in a dynamic loads environment, it is imperative that efficient automated structural sizing procedures be developed that adequately account for these complexities. Furthermore, an increasing focus on multidisciplinary design and optimization dictates a realistic representation of each participating discipline.

The optimum sizing of airframe structures is performed in a complex analysis environment where structural stability must be carefully monitored in addition to elastic deformation under static and dynamic loads. Hence an analysis tool that accounts for the interaction of structural deformations and unsteady airloads, is a necessary ingredient to the development of any synthesis capability. The present report documents the framework of an optimization system, developed around the ISAC computer program (Ref. 3), with SPAR (Ref. 4) and CONMIN (Ref. 5) as the structural analysis and optimization programs, respectively. The NOS control language feature on the CDC Cyber computer is used to direct the flow between various segments of the system. In its present form, the system retains a degree of modularity, permitting substitutions of the analysis packages.

The thrust of the present work was directed towards establishing an optimization capability for sizing airframe structures that are subjected to a combination of deterministic and random flight loads. The random vibration environment introduces the need for selecting a statistical process that best describes the random loads and permits computation of the dynamic response parameters of interest. Furthermore, it requires a formulation of design constraints that would minimize the conservativeness in the design and retain computational viability. In the present work, the random loads are treated as a stationary, homogeneous process with a Gaussian probability distribution. A frequency domain analysis is selected for the solution of the dynamic response problem. This permits a power spectral density input for the gust velocities, a representation that is typically available from experimental observations. The ISAC system of programs has the feature to incorporate aribitrary gust velocity input spectra.

Subsequent sections of this report discuss the formulation of the analysis problem, the structure of the optimization programming system and a representative numerical example. An appendix with procedure files and FORTRAN pre- and post-processor listings is included for completeness.

N86-20386 #

Dynamic Response Analysis

In a frequency domain analysis, the system equations of motion can be written as

$$(-\omega^2[M] + [K] - [A])\{W\} = \{G\} \tag{1}$$

where [M] and [K] are the mass and stiffness matrices, respectively; $\{W\}$ is the displacement vector; [A] is the matrix of loads due to oscillation at frequency ω, and $\{G\}$ is the force coefficient array per unit gust velocity. As is typical of large structural configurations, a modal approach is adopted wherein a finite number of elastic modes are used to model the structural deformations. The displacement $\{W\}$ can be represented approximately by the superposition of the characteristic modes

$$\{W\} = [\phi]\{\xi\} \tag{2}$$

where $[\phi]$ is the matrix of 'm' normalized eigenmodes and $\{\xi\}$ is an m-dimensional vector of generalized coordinates. Substituting equation (2) into equation (1) and then transforming the resulting equation from the frequency domain into the Laplace domain yields the equations of motion in the following form

$$[M_{\xi\xi}s^2 + (1 + ig)M_{\xi\xi}\omega_\xi^2 - A_{\xi\xi}]\{\xi\} = \{\bar{G}\} \tag{3}$$

where $M_{\xi\xi}$ is the generalized mass matrix; $A_{\xi\xi}$ and $\bar{G}$ are the generalized aerodynamic force matrices due to motion and gust respectively; g is the structural damping coefficient and ω_ξ^2 is the natural frequency associated with the ξ-th generalized coordinate. Equation 3 is a system of linear, nonhomogenous equations that are solved for the vector of generalized coordinates. A similar approach can be adopted to include a control surface, and the option to do so exists in the ISAC system.

Typical response parameters for which design constraints can be formulated include stresses, nodal displacements, and accelerations at specified locations. The focus of the present work was in implementing structural reliability constraints for which element stresses are the primary response quantities of interest. In the modal displacement approach, the stress at a location j is computed as

$$S_j = \sum_i c_{ij}\xi_i \tag{4}$$

where c_{ij} is the stress coefficient at location 'j' due to a unit displacement in the i-th generalized coordinate ξ_i. For a random gust input, these quantities are obtained as root mean square (rms) values which are then used in the constraint formulation.

Structural Reliability Constraints

For a structure subjected to random gust loads, failure can be caused by a single overstress or as a result of cumulative damage in fatigue. These failure conditions are termed by Johnson (Ref. 6) as single excursion and fatigue, respectively. Constraints must be formulated for both these failures modes. For a stress response S(t) that is stationary and has a Gaussian probability distribution, an assumption that large values of S(t) arrive independently, leads to a Poisson probability function for the number of times 'n' that a large magnitude $\bar{S}$ is exceeded in time 't'. If the occurrence of this large stress magnitude is not permitted in time $\bar{T}_s$, the single excursion constraint, $g_{S \cdot E}$, can be written as

$$g_{S \cdot E} \equiv \frac{\bar{T}_s}{\pi} \frac{\sigma_{\dot{s}}}{\sigma_s} \exp \left(- \frac{\bar{S}^2}{2 \sigma_s^2} \right) - 1 \leqslant 0 \tag{5}$$

Fatigue damage can be estimated on the basis of the Palmgren-Miner theory and results in a fatigue constraint, g_F, of the following form

$$g_F \equiv \frac{\sigma_{\dot{s}} L_f}{\pi c} (2)^{\frac{b-2}{2}} \sigma_s^{b-1} \Gamma \left(\frac{b+2}{2}\right) - 1 \leqslant 0 \tag{6}$$

where, L_f is the specified fatigue life; Γ is the gamma function; σ_s and $\sigma_{\dot{s}}$ are the rms values of the stress and stress rates and b and c are constants obtained from empirical relations for different materials.

Failure constraints derived from a fracture mechanics standpoint have also been proposed (Ref. 7) where the constraints expressed in equations (5) and (6) are essentially unified into a single constraint. The initiation and propagation of cracks in a material results in both a reduced allowable stress and can also be viewed as accumulated damage in the structure. In the present work constraint equations (5) and (6) were implemented in the design.

Optimization System

This section of this report gives a brief description of the optimization system and its component programs. The optimization system combines a finite element program SPAR, a general-purpose, nonlinear programming-based optimization program CONMIN, and a system of aeroelastic response analysis programs ISAC. The flow between these programs is controlled in a manner similar to the PROSSS system for optimum design (Ref. 8). The role of each of these programs is discussed next. The reader is referred to Appendix A for a listing of the various routines described in this section.

SPAR

The program is a system of independent processors which communicate with each other through a data base which consists of libraries of named data sets. The structural model geometry definition, material specification and element connectivity are defined in a SPAR input runstream NREPT, and the data set library is stored as NRLA. This is the non-repeatable part of the structural analysis program and does not have to be re-executed as the program iterates in the optimization mode. The SPAR program is used to generate for the ISAC system, quantities such as mode-shapes, eigenvalues, generalized masses and stress coefficients defined in equation (4). It is also used to generate finite-difference gradients for the eigenmodes and frequencies. A FORTRAN program GRAD generates an input runstream corresponding to the set of new design variables. This input runstream, SECPROP, is executed before the repeatable segment REPT is called to obtain the new response parameters. A FORTRAN program EIGSTR employs the SPAR data handling utilities (Ref. 9) to extract the desired information from the data set libraries and store the information for post processing.

ISAC

The ISAC system of routines is employed to compute the aeroelastic response of the flight vehicle. The structural node deflections corresponding to the vibration modes obtained in SPAR are related to the deflections and slopes on aerodynamic boxes by a 2-D, spline interpolation technique in DLIN. These aerodynamic slopes and deflections are used by a doublet lattice program DLAT, in the computation of the generalized aerodynamic forces for a range of reduced frequencies. The generalized mass, stiffness and aerodynamic matrices are passed to the routine DYNARES where a gust spectrum is selected and the aeroelastic response parameters are obtained. For a random gust input, the rms responses can be computed by numerical integration of the response spectra within this routine. In the present organization, however, DYNARES writes a state space representation of the system equations and passes the system matrices to another group of programs PADLOCS (Ref. 10), where the rms responses are computed. Additionally, this program provides correlation coefficients between various response components which are required in the formulation of stress constraints in the event of a combined stress failure criterion (Ref. 11). The input files required for ISAC execution are listed in Appendix A. For a detailed description of the input parameters, the reader is referred to Reference 3.

CONMIN

CONMIN is a general purpose optimization subroutine for solving constrained and unconstrained, linear or nonlinear, continuous problems. It is based on the method of feasible-usable search directions (Ref. 5) and was adapted in the present framework in a piecewise linear mode of operation. The general optimization problem for CONMIN can be posed as follows

Minimize a function

$$F(d_1, d_2 \ldots d_n) \qquad (7)$$

Subject to the inequality constraints

$$g_j(d_1, d_2, \ldots d_n) \leqslant 0 \qquad j = 1,2,\ldots m \qquad (8)$$

and the side constraints on the design variables d_i

$$d_i^l \leqslant d_i \leqslant d_I^u \qquad i = 1,2,\ldots n \qquad (9)$$

In general, both the objective function and constraints can be nonlinearly dependent on the design variables. In a piecewise linear mode of operation, the objective function and design constraints are regarded to be linear functions of the design variables, eliminating the need to compute function derivatives at every iteration for a general nonlinear problem. A linear approximation to a general nonlinear problem requires that constraints be imposed on design variable change for a given cycle of optimization. An appropriate choice of design variables (reciprocal variables) will often enhance the linearity in the design space.

Program Organization

A flow chart depicting the implementation of the optimization system is shown in Figure 1. The corresponding procedure file PRLOOP is listed in Appendix A. The structural model is initialized for the starting design and the eigenmodes, natural frequencies and response coefficients and their sensitivity to perturbations in design variables are computed. This information is then used to compute the response constraints sensitivity in a finite difference operation. The two sensitivity computations were separated on purpose. If the eigenvalue and eigenvector sensitivities are assumed constant, the outer gradient loop can be executed once in the optimization sequence. The inner gradient loop for constraint sensitivities is the only required operation for subsequent cycles of optimization. By the same token, if the eigenvalue/eigenmode sensitivities are known to be more nearly constant over a wider variation in design variables, the outer loop can be executed a lesser number of times in the optimization sequence. The objective function, constraints and their gradients are passed to an optimization program where the design variables are altered within the limits imposed by the side constraints. This sequence is repeated until convergence.

Numerical Examples

A built up finite element model of a wing structure was developed as a test problem for the program implementation described in the preceeding sections. The cross-section and planform of this stringer-membrane, cantilever structure is shown in Figures 2 and 3. The model element sizes were preprocessed by a fully-stresssed design cycle for 1-g cruise loads. These member sizes were established as the lower bounds for the gust design. A Dryden spectrum with a gust intensity of 2.54 m/sec (typical of storm conditions) was specified in the input. The first six elastic modes were chosen to represent the structural deformation and were considered adequate for such a cantilever structure. In more realistic designs for gust loads, rigid body modes in plunge and pitch should also be included. The addition of these in the present system constitutes no added complexity. The design variables selected for this minimum weight design were the cross-sectional areas of the bar elements. An allowable stress of 1761.4 kg/cm^2 was used in the computation of the first excursion failure constraints. First excursion and fatigue failure lives of 2 years were specified in the design process. The design converged in 13 piecewise linear cycles to the values shown in Table 1. The first cantilever mode in bending dominates the stress distribution in the structure, as is evidenced by a concentration of material at the root section. The first excursion constraint is active at the optimum.

Concluding Remarks

This report documents the development and implementation of an optimization system around ISAC for the structural design of airframe structures with aeroelastic constraints. The programming system is regarded as the necessary first step for further studies in the systematic design of aircraft structures, operating in a random gust load environment. Although developed primarily for the design of structures under random gust loads, the program in its present form is suitable for inclusion of static stress, displacement and frequency constraints. An s-plane formulation of the flutter constraint can also be added with minor modifications. These features coupled to a built-in control analysis capability, make this programming system an extremely powerful tool for multidisciplinary analysis and design. Furthermore, the programming system provides a natural test-bed for multilevel optimization studies. The computational efficiency of the system can be significantly enhanced with the inclusion of an analytical gradient capability.

References

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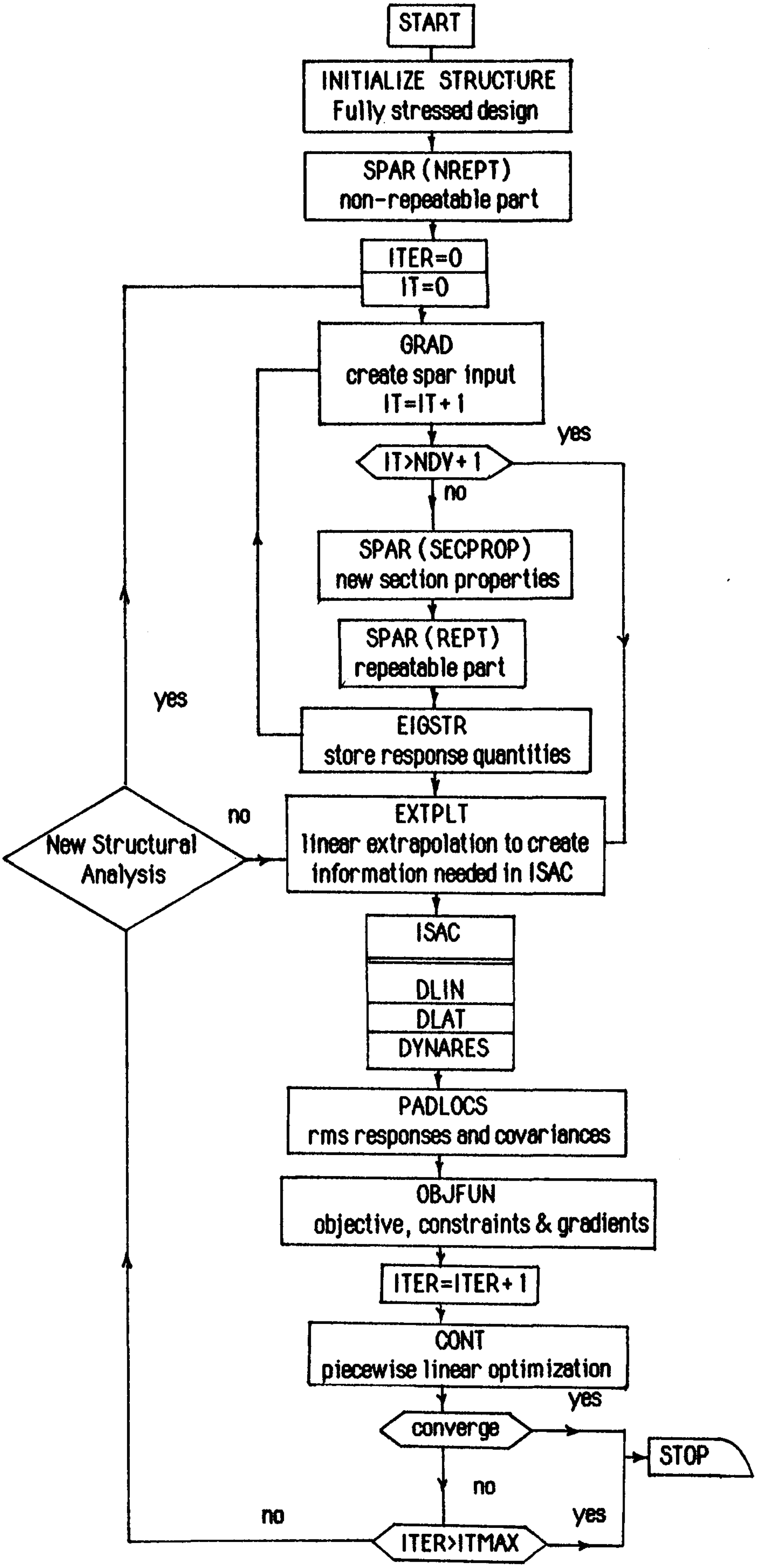

Figure 1. Flowchart depicting the organization of the optimization system

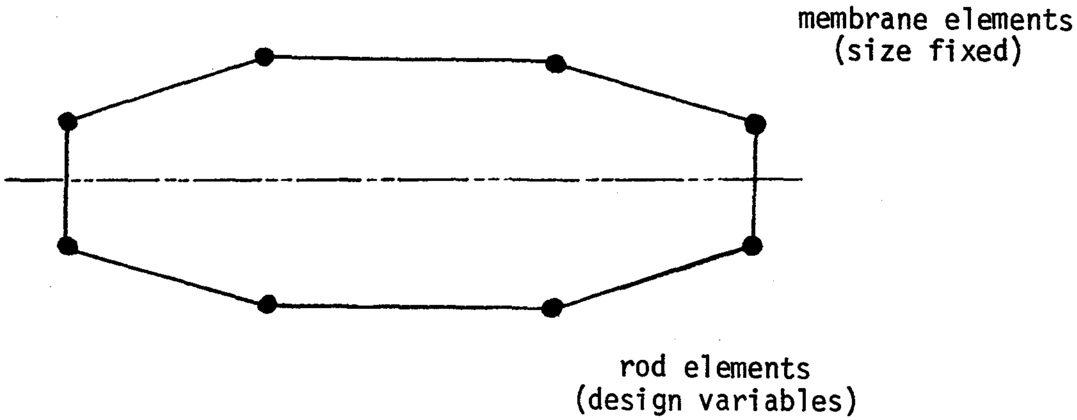

Figure 2. Cross section of wing structural box

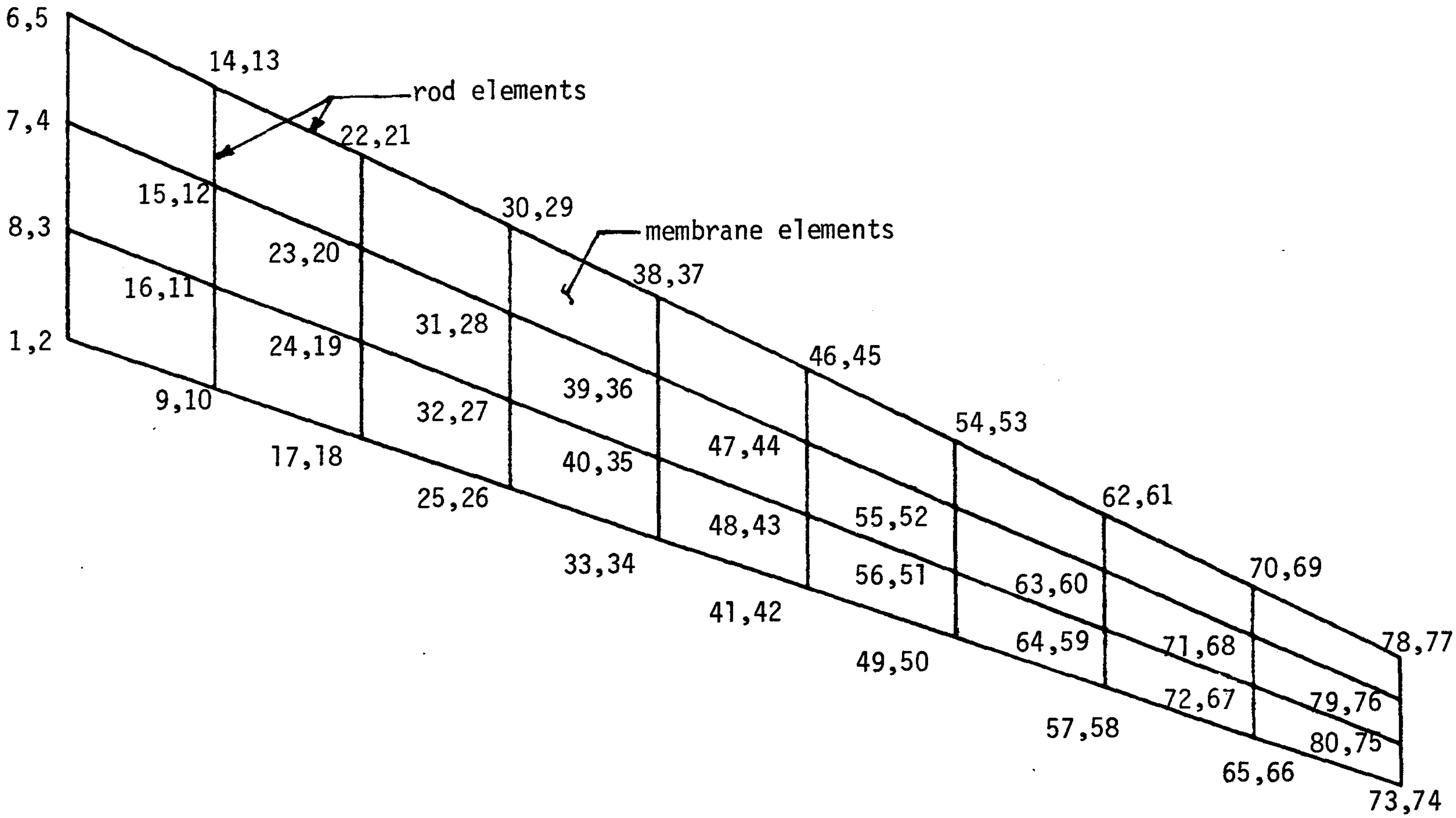

Figure 3. Finite element model of Wing Structural Box. Node numbers n1, n2 represent lower and upper surface co-ordinates, respectively. Panel elements were sized by a fully-stressed design approach.

Design Variable	Element Connectivity	Initial Design (cm^2)	Minimum Gage (cm^2)	Final Design (cm^2)
1	1-9,9-17,8-16,16-24 7-15,15-23,6-14,14-22	10.3226	10.1096	17.9516
2	17-25,25-33,24-32,32-40 22-30,30-38,23-31,31-39	10.3226	4.6297	9.4458
3	33-41,41-49,40-48,48-56 39-47,47-55,38-46,46-54	10.3226	0.6452	2.5239
4	2-10,10-18,3-11,11-19 4-12,12-20,5-13,13-21	10.3226	10.1096	17.9574
5	18,26,26-34,19-27,27-35 20-28,28-36,21-29,29-37	10.3226	4.6309	9.5703
6	34-42,42-50,35-43,43-51 36-44,44-52,37-45,45-53	4.516	0.6452	2.5298
7	54-62,62-70,70-78 55-63,63-71,71-79 56-64,64-72,72-80 49-57,57-65,65-73	4.516	0.6452	1.1761
8	53-61,61-69,69-77 52-60,60-68,68-76 51-59,59-67,67-75 50-58,58-66,66-74	4.516	0.6452	0.9661
Objective	Function Weight	286.33 Kg	195.56	270.41 Kg

Table 1. Numerical results for the cantilevered wing structural box

Appendix A

```
LIST,FN=SUBFIL
PRLOOP,T6000.
USER,358625C,PATHA.
CHARGE,102632,LRC.
DELIVER.1229 PH PROC TEST CASE
*
*  THIS FILE IS  PRLOOP
*
MAP,OFF.
BEGIN,PRLOOP.
COPYSBF,INPUT,OUTPUT.
DAYFILE,L=DAYPRLP.
REPLACE,DAYPRLP.
EXIT.
COPYSBF,INPUT,OUTPUT.
DAYFILE,L=DAYPRLP.
REPLACE,DAYPRLP.
 EOI ENCOUNTERED.
/
```

Above procedure file is used to initiate a batch run for optimization.

PROCFIL is a listing of all procedure files used in the present optimization system.

```
LIST,FN=PROCFIL
.PROC,DYNA.
GET,DCM=DCMV2A/UN=887010N.
GET,DYNARES=DYNAV3A/UN=887010N.
REVERT.
.PROC,CONT.
GET,CONMINB/UN=753437N.
GET,CONB.
COPYBR,CONB,PRAT.
COPYBF,CONMINB,PRAT.
GET,DESIGN,OLDOBJ,CONMDT,CONPAR.
REWIND,*.
PRAT.
REWIND,TAPE6.
APPEND,CONOUT,TAPE6.
REPLACE,OLDOBJ.
REPLACE,DESIGN.
REVERT.
.PROC,OBFUN.
RETURN,*.
GET,OBJFUB,DECIS,ITER,DESIGN,CVD1,OBDJ.
PACK,CVD1.
OBJFUB.
REPLACE,CONMDT.
RETURN,*.
REVERT.
.PROC,DYNDES.
GET,TAP2G.
BEGIN,DYNA.
BEGIN,PRDES.
BEGIN,DYNA.
BEGIN,PRDES.
BEGIN,DYNA.
BEGIN,PRDES.
BEGIN,DYNA.
BEGIN,PRDES.
BEGIN,DYNA.
BEGIN,PRDES.
BEGIN,DYNA.
BEGIN.PRDES.
BEGIN,DYNA.
BEGIN,PRDES.
BEGIN.DYNA.
BEGIN,PRDES.
BEGIN,DYNA.
BEGIN,PRDES.
REVERT.
.PROC,PRGUST.
GET,TAPE5=POUT.
```

```
BEGIN,DCM.
DCM,,,,,DCMIN1.
RETURN,DCM,TAPE5.
REWIND,TAPE9.
REPLACE,TAPE9=PHT9.
BEGIN,DLIN.
GET,TAPE1=W2POS1,TAPE3=TAPE31,TAPE5.
DLIN.
REWIND,*.
RETURN,TAPE1,TAPE3.
GET,TAPE1=W2POS2,TAPE3=TAPE32.
DLIN.
REWIND,*.
RETURN,TAPE1,TAPE3.
GET,TAPE1=W2POS3,TAPE3=TAPE33.
DLIN.
REWIND,*.
REPLACE,TAPE9=PHT9.
RETURN,*.
REVERT.
.DATA,DCMIN1.
BATCH
STORE
GMASS -1 1 324 1
F
GENERALIZED MASSES
STORE
FREQ -1 1 18 1
F
FREQUENCIES IN HZ
STORE
LOADS -1 1 1296 1
F
STRESS COEFFICIENTS
STORE
DAMPINGS -1 1 18 1
F
DAMPING COEFFICIENTS
STORE
GMASS -1 2 324 1
F
GENERALIZED MASSES
STORE
FREQ -1 2 18 1
F
FREQUENCIES IN HZ
STORE
LOADS -1 2 1296 1
F
STRESS COEFFICIENTS
STORE
DAMPINGS -1 2 18 1
F
DAMPING CONSTANTS
STORE
```

```
GMASS -1 3 324 1
F
GENERALIZED MASSES
STORE
FREQ -1 3 18 1
F
FREQUENCIES IN HZ
STORE
LOADS -1 3 1296 1
F
STRESS COEFFICIENTS
STORE
DAMPINGS -1 3 18 1
F
DAMPING CONSTANTS
END
.PROC,PRDES.
GET,TAPE9=PHT9.
COPYBR,TAP2G,TAPE2.
REWIND,TAPE2.
DYNARES.
REPLACE,TAPE1=TAPE7.
RETURN,*,TAP2G.
GET,DESDAT,TAPE7,DESIGN=DEZIGN.
DESIGN,DESDAT.
REWIND,CVDATA.
GET,REDUB.
REDUB.
APPEND,CVD1,CVDATA.
RETURN,*,TAP2G.
REVERT.
.PROC,PREXT.
GET,EXTPLB,DECIS,DESIGN,CONDAT,ITER,NODAL.
REWIND,*.
EXTPLB.
REWIND,*.
REPLACE,WPOS=W2POS1,WPOS1=W2POS2,WPOS2=W2POS3.
REPLACE,POUT.
REVERT.
.PROC,STORE.
GET,EIGSTRB,ITER,GRDATA,LOO1=RRLA.
REWIND,*.
EIGSTRB.
REPLACE,GRDATA.
REVERT.
.PROC,PRLOOP.
SET(R2=10)
SET(R3=0)
1OPT,CTIME.
SET(R1=0)
MAP,OFF.
WHILE,R1.LT.R2,FIN1.
SET(R1=R1+1)
DISPLAY(R1)
GET,GRADB,ITER,DECIS,GRDATA,OBDJ.
GRADB.
```

```
REPLACE,ITER,CONDAT,OBDJ.
RETURN,GRDATA.
IFE,R1.LT.R2,JMP1.
BEGIN,PRRSPAR.
BEGIN,STORE.
RETURN,*.
ENDW,FIN1.
ENDIF,JMP1.
BEGIN,PREXT.
BEGIN,PRGUST.
GET,TAPE5=TAPE5T,TAPE9=PHT9.
BEGIN,DLAT.
ALPHA.
REPLACE,TAPE9=PHT9.
RETURN,*.
BEGIN,DYNDES.
BEGIN,OBFUN.
GET,CVD1=CV.
REPLACE,CVD1.
SET(R3=R3+1)
BEGIN,CONT.
GET,DECIS,DESIGN,ITER,POSB.
POSB.
REPLACE,DECIS.
IFE,R3.LT.9,JMP2.
IFE,FILE(IFLG,.NOT.AS),JMP3.
RETURN,*.
GOTO,1OPT.
ENDIF,JMP2.
ENDIF,JMP3.
REVERT.
.PROC,PRCSTR,XXX=W2ZPOS.
*
* EXECUTE THIS PROCEDURE AS FOLLOWS:
* -DLNPROC,DLNPROC.
*
RETURN,LGO.
GET,DLNLIB.
*PUT HERE A GET TO YOUR TAPE5 - INPUT FILE
*NEXT MAKE AVAILABLE A  SPAR FILE WHICH TO EXTRACT DATA FROM
GET,LOO1=RRLA.
GET,X=EIGSTR.
GET,GRDATA,ITER.
REWIND,X,ITER,GRDATA.
FTN,I=X,L=0,OPT=0,STATIC.
GTR,LGO,LL.REL/EIGSTR
GTR,DLNLIB,LL.REL/BLKDAT.
RENAME,LGO=LL.
LDSET(LIB=DLNLIB,MAP=SBEX/OUT)
LOAD,LGO.
NOGO(EIGSTRB).
REVERT.
.PROC,PRRSPAR.
.*
.*  REPEATABLE SPAR
.*
```

PRLOOP is the procedure file to execute the various segments of the optimization sequence.

```
GET,SPAR=SPAR14I,DCU=DCU14I/UN=750756N.
GET,SPARLA=NRLA.
REWIND,SECPROP.
SPAR,SECPROP,SPOUT.
RETURN,SPOUT.
REWIND,*.
GET,REPT.
SPAR,REPT,SPOUT.
REWIND,SPARLA.
REPLACE,SPARLA=RRLA.
RETURN,*.
REVERT.
.PROC,PRNSPAR.
.*
.* NONREPEATABLE SPAR
.*
GET,SPAR=SPAR14I,DCU=DCU14I/UN=750756N.
GET,NREPT.
SPAR,NREPT,SPOUT.
REPLACE,SPARLA=NRLA.
RETURN,*.
REVERT.
.PROC,DLIN.
GET,DCM=DCMV2A/UN=887010N.
GET,DLIN=DLINV3A/UN=887010N.
REVERT.
.PROC,DLAT.
GET,DCM=DCMV2A/UN=887010N.
GET,ALPHA=DLATV5A/UN=887010N.
REVERT.
.PROC,DCM.
GET,DCM=DCMV2A/UN=887010N.
REVERT.
.PROC,PLOT.
REWIND,SAVPLT.
PLOT.TEKPOST,TE(AUTO(0)).
NOTE./:G507>
REVERT.    WHAT A CRUMMY PLOT!!
.PROC,PLTRVAX.
REWIND,SAVPLT.
PLOT.TEKPOST,TE(AUTO(0).RVAX).
NOTE./:G507>
REVERT.
 EOI ENCOUNTERED.
/
```

```
LIST,FN=CONT
      PROGRAM CONOPT(CONPAR,OLDOBJ,DESIGN,CONMDT,IFLG,
     *TAPE56=CONPAR,TAPE12=OLDOBJ,
     *TAPE31=DESIGN,TAPE22=CONMDT,TAPE14=IFLG,OUTPUT,
     *TAPE6)
C
C ************************************************************
C
C  THIS IS THE OPTIMIZER WITH PIECEWISE LINEAR APPROXIMATION
C
C  PRABHAT HAJELA  JUNE 1985
C
C ************************************************************
C
      COMMON/CNMN1/DELFUN,DABFUN,FDCH,FDCHM,CT,CTMIN,CTL,CTLMIN,
     *ALPHAX,ABOBJ1,THETA,OBJ,NDV,NCON,NSIDE,IPRINT,NFDG,NSCAL,LINOBJ,
     *ITMAX,ITRM,ICNDIR,IGOTO,NAC,INFO,INFOG,ITER
      COMMON/CNMN2/RDUM(50),IDUM(50)
      COMMON/CONSAV/REAL(50),INT(25)
      DIMENSION X(50),VLB(50),VUB(50),G(200),SCAL(50),
     *DF(50),A(50,200),S(50),G1(200),G2(200),B(200,200),
     *C(200),ISC(200),IC(200),MS1(400)
      DIMENSION VLBTMP(50),VUBTMP(50),XINIT(50),GI(200),
     *GRDG(50,200),GRDOBJ(50)
      DATA NDV/8/,NCON/144/
C
C
C  COMPUTE CONMIN DIMENSIONS
C
      NLIM1=NDV+1
      N1=NDV+2
      N2=NCON+2*NDV
      N3=N2+5
      N4=MAX0(N3,NDV)
      N5=2*N4
C
C
C  READ CONMIN PARAMETERS
C
      READ(56,*)NITER,IPRINT,NSIDE,NFDG,LINOBJ,ITMAX,ICNDIR,NSCAL,
     *ITRM,IGOTO,NDV,NCON,FDCH,FDCHM,CT,CTMIN,CTL,CTLMIN,THETA,PHI,
     *DELFUN,DABFUN,ALPHAX,ABOBJ1
C
C  READ OLD OBJECTIVE FUNCTION VALUES
C
      READ(12,*)OBJ1,OBJ2,OBJ3,TOL
C
      DO 5 I=1,NCON
5     ISC(I)=0
C
C  PRESCRIBE BOUNDS ON DESIGN VARIABLES FOR OVERALL OPTIMIZATION
C
```

```
      VLBTMP(1)=1.567
      VLBTMP(2)=0.7176
      VLBTMP(3)=0.1
      VLBTMP(4)=1.567
      VLBTMP(5)=0.7178
      VLBTMP(6)=0.1
      VLBTMP(7)=0.1
      VLBTMP(8)=0.1
      DO 6 I=1,NDV
      VUBTMP(I)=5.0
6     CONTINUE
C
C  READ INITIAL DESIGN VARIABLES
C
      READ(31,*)(XINIT(I),I=1,NDV)
C
C  PRESCRIBE BOUNDS FOR LOCAL OPTIMIZATION CYCLE
C
      DO 12 I=1,NDV
      VUB(I)=1.4*XINIT(I)
      VLB(I)=0.6*XINIT(I)
      X(I)=XINIT(I)
      IF(VUB(I).GT.VUBTMP(I))VUB(I)=VUBTMP(I)
      IF(VLB(I).LT.VLBTMP(I))VLB(I)=VLBTMP(I)
12    CONTINUE
C
C READ INITIAL FUNCTION AND GRADIENT INFORMATION
C
      READ(22,*)(GI(I),I=1,NCON),OBJ1
     *,((GRDG(I,J),I=1,NDV),J=1,NCON),
     *(GRDOBJ(I),I=1,NDV)
      OBJ=OBJ1
100   CONTINUE
C
C  CALL TO CONMIN OPTIMIZER
C
      CALL CONMIN(X,VLB,VUB,G,SCAL,DF,A,S,G1,G2,B,C,
     *ISC,IC,MS1,N1,N2,N3,N4,N5)
C
      IF(IGOTO.EQ.0)GO TO 555
      IF(INFO.EQ.2)GO TO 24
C
C  FUNCTION AND CONSTRAINT VALUES
C
      SUM=OBJ1
      DO 23 I=1,NDV
      DX=X(I)-XINIT(I)
      SUM=SUM+GRDOBJ(I)*DX
23    CONTINUE
      OBJ=SUM
      DO 22 J=1,NCON
      SUM=GI(J)
      DO 21 I=1,NDV
      DX=X(I) - XINIT(I)
21    SUM=SUM+GRDG(I,J)*DX*(XINIT(I)/X(I))
      G(J)=SUM
22    CONTINUE
      GO TO 100
24    CONTINUE
```

```
C
C  GRADIENT INFORMATION
C
      DO 25 I=1,NDV
25    DF(I)=GRDOBJ(I)
      NAC=0
      DO 26 J=1,NCON
      IF(G(J).LT.CT)GO TO 26
      NAC=NAC+1
      IC(NAC)=J
26    CONTINUE
      DO 27 I=1,NDV
      DO 28 J=1,NAC
      J1=IC(J)
      A(I,J)=GRDG(I,J1)
28    CONTINUE
27    CONTINUE
C
      GO TO 100
C
C  TERMINATE OPTIMIZATION LOOP
C
555   CONTINUE
      REWIND 31
      WRITE(31,*)(X(I),I=1,NDV)
C
C  TEST FOR CONVERGENCE OVER THREE CYCLES
C
      OBJ3=OBJ2
      OBJ2=OBJ1
      OBJ1=OBJ
      REWIND 12
      WRITE(12,*)OBJ1,OBJ2,OBJ3,TOL
      IF(ABS(OBJ2).LE.0.0001)GO TO 666
      DA=ABS((OBJ3-OBJ2)/OBJ2)
      DB=ABS((OBJ2-OBJ1)/OBJ2)
C
C  TERMINATE PROGRAM
C
      IF(DA.GT.TOL.OR.DB.GT.TOL)GOTO 666
      WRITE(14,*)NCON
666   CONTINUE
      STOP
      END
 EOI ENCOUNTERED.
/
```

```
LIST,FN=EIGSTR
      PROGRAM EIGSTR(GRDATA,ITER,TAPE2=ITER,TAPE32=GRDATA,
     *OUTPUT)
C
C ************************************************************
C
C  THIS PROGRAM READS AND STORES THE DATA REQUIRED FOR
C  THE EIGENANALYSIS AND STRESS COEFFICIENT GRADIENTS
C
C  PRABHAT HAJELA  JUNE 1985
C
C ************************************************************
C
      DIMENSION G1(100),G2(13000),G3(10000),G4(10),X(10),Y(10)
      DIMENSION AMODE(3,80),FREQ(25),STRS(72,6,1),STR1(10000)
      DATA NLIB/1/,NMODE/6/,ND41/10/,NSTR/72/,PI/3.14159/
     *,NNODE/80/,NELT/72/,NDOF/240/
C
C  READ FREQUENCY
C
      CALL DAL(NLIB,11,FREQ,0,0,KADL,IERR,NW,NE,LB,IT,
     *4HVIBR,4HEVAL,4HMASK,4HMASK)
C
C  STRESS COEFFICIENTS
C
      CALL DAL (NLIB,11,STR1(1),0,0,KADL,IERR,NW,NE,LB,IT,
     1 4HSTRS,4HE23 ,1,1)
      CALL DAL (NLIB,11,STR1(433),0,0,KADL,IERR,NW,NE,LB,IT,
     1  4HSTRS,4HE23 ,1,2)
      CALL DAL (NLIB,11,STR1(865),0,0,KADL,IERR,NW,NE,LB,IT,
     1 4HSTRS,4HE23 ,1,3)
      CALL DAL (NLIB,11,STR1(1297),0,0,KADL,IERR,NW,NE,LB,IT,
     1  4HSTRS,4HE23 ,1,4)
      CALL DAL (NLIB,11,STR1(1729),0,0,KADL,IERR,NW,NE,LB,IT,
     1  4HSTRS,4HE23 ,1,5)
      CALL DAL (NLIB,11,STR1(2161),0,0,KADL,IERR,NW,NE,LB,IT,
     1  4HSTRS,4HE23 ,1,6)
C
C OBJECTIVE
C
      CALL DAL(NLIB,11,OBJP,0,0,KADL,IERR,NW,NE,LB,IT,
     *4HOBJF,4HAUS ,4HMASK,4HMASK)
C
C  EIGENMODES
C
      CALL DAL (NLIB,10,AMODE,0,0,KADR,IERR,NWDS,NE,LB,IT,
     1 4HVIBR,4HMODE,4HMASK,4HMASK)
C
C
      READ(2,*)ITER,NDV
      NCOEF=NELT*NMODE
      NLIM1=NDV+1
      NLIM2=NMODE*NLIM1
      NLIM3=NCOEF*NLIM1
      NLIM4=NDOF*NLIM1*NMODE
```

```
C
C   IF ITER.EQ.0 CREATE GRDATA
C
        IF(ITER.GT.0)GO TO 2000
        DO 1000 I=1,NLIM2
1000    G1(I)=0.0
        DO 1001 I=1,NLIM4
1001    G2(I)=0.0
        DO 1002 I=1,NLIM3
1002    G3(I)=0.0
        DO 1003 I=1,NLIM1
        G4(I)=0.0
1003    CONTINUE
        WRITE(32,*)(G1(I),I=1,NLIM2),
       *(G2(I),I=1,NLIM4),
       *(G3(I),I=1,NLIM3),
       *(G4(I),I=1,NLIM1)
2000    CONTINUE
C
        REWIND 32
C   IF ITER.GT.0 READ DATA FROM OLD GRDATA FILE
C
        READ(32,*)(G1(I),I=1,NLIM2),
       *(G2(I),I=1,NLIM4),
       *(G3(I),I=1,NLIM3),
       *(G4(I),I=1,NLIM1)
        REWIND 32
C
C   STORE DATA
C
C   OBJECTIVE
C
        G4(ITER+1)=OBJF
C
C   FREQUENCY
C
        DO 2 I=1,NMODE
        FREQCY=SQRT(FREQ(I))/(2.*PI)
        K=(ITER*NMODE)+I
        G1(K)=FREQCY
2       CONTINUE
C
C   EIGENMODES
C
        ID=ITER*NDOF*NMODE
        DO 4 I=1,NMODE
        KS=KADR + (I-1)*NSECTS(LB)
        CALL RIO(NLIB,2,2,KS,AMODE,LB)
        DO 6 J=1,NNODE
        DO 7 K=1,3
        ID=ID+1
        G2(ID)=AMODE(K,J)
7       CONTINUE
6       CONTINUE
4       CONTINUE
C
C   STRESS COEFFICIENTS
C
```

```
      ID=ITER*NCOEF
      JC=0
      DO 8 I=1,NMODE
      ID1=(I-1)*NELT*6
      DO 9 J=1,NELT
      ID2=(J-1)*6 + 5 + ID1
      IDK=ID2+1
      ID=ID+1
      G3(ID)=STR1(IDK)
9     CONTINUE
8     CONTINUE
C
C  WRITE OBJECTIVE,EIGEN-INFO AND STRESS COEFFICIENTS
C
      WRITE(32,*)(G1(I),I=1,NLIM2),
     *(G2(I),I=1,NLIM4),
     *(G3(I),I=1,NLIM3),
     *(G4(I),I=1,NLIM1)
      REWIND 32
      STOP
      END
 EOI ENCOUNTERED.
/
```

```
LIST,FN=EXTPLT
      PROGRAM EXTPLT(DECIS,DESIGN,CONDAT,POUT,NODAL,ITER,
     *WPOS,WPOS1,WPOS2,
     *TAPE33=DESIGN,TAPE22=CONDAT,TAPE7=POUT,TAPE1=NODAL,
     *TAPE4=WPOS1,TAPE8=WPOS2,
     *TAPE31=DECIS,TAPE9=ITER,TAPE3=WPOS,INPUT,OUTPUT)
C
C *******************************************************
C
C  THIS PROGRAM PROVIDES A NEW SET OF EXTRAPOLATED MODES
C  EIGENFREQUENCIES AND RESPONSE COEFFICIENTS TO ANALYSIS
C
C  PRABHAT HAJELA  JUNE 1985
C
C *******************************************************
C
      DIMENSION G1(100),G2(1500),G3(1100),G4(10),DD(60)
      DIMENSION GRDG(8,1500),GRDG1(8,1100),GRDG2(8,10),
     *GRDOBJ(10)
      DIMENSION NODE(80),X(10),Y(10),XX(10),AMODE(6,3,80)
      DIMENSION G(1000),FREQ(10),DELT(10),VECN(1500)
      DIMENSION GMAS(54,54),S1(100),S2(10000),STRS(72,54,1)
      DATA NMODE/6/,NDOF/240/,NELT/72/,NE41/10/,
     *NSNODE/40/,NNODE/80/
      OPEN(UNIT=7,FILE='POUT')
      OPEN(UNIT=1,FILE='NODAL')
      OPEN(UNIT=33,FILE='DESIGN')
      OPEN(UNIT=22,FILE='CONDAT')
      OPEN(UNIT=31,FILE='DECIS')
      OPEN(UNIT=9,FILE='ITER')
      OPEN(UNIT=3,FILE='WPOS')
      OPEN(UNIT=4,FILE='WPOS1')
      OPEN(UNIT=8,FILE='WPOS2')
      READ(9,*)ITER,NDV
      NCOEF=NELT*NMODE
      N1=NDOF*NMODE
      NLIM1=NDV+1
      NLIM2=NMODE*NLIM1
      NLIM3=NCOEF*NLIM1
      NLIM4=NDOF*NLIM1
      NSTR=NELT
      DO 40 I=1,18
      DO 41 J=1,18
      GMAS(I,J)=0.0
      IF(I.EQ.J)GMAS(I,J)=1.0
 41   CONTINUE
 40   CONTINUE
      READ(31,*)(X(I),I=1,NDV),(Y(I),I=1,NE41),FDCH
      READ(1,*)(NODE(I),I=1,NSNODE)
      READ(22,*)(G1(I),I=1,NMODE),(G2(I),I=1,N1),
     *(G3(I),I=1,NCOEF),G4(1),
     *(GRDOBJ(I),I=1,NDV),
     *((GRDG(I,J),I=1,NDV),J=1,N1),
     *((GRDG2(I,J),I=1,NDV),J=1,NMODE),
     *((GRDG1(I,J),I=1,NDV),J=1,NCOEF)
```

```
        DO 30 INN=1,NLIM1
        READ(33,*)(XX(I),I=1,NDV)
        REWIND 33
        IF(INN.EQ.1)GO TO 31
        XX(INN-1)=XX(INN-1)*(1.+FDCH)
31      CONTINUE
C
C   UPDATE STRESS COEFFICIENTS
C
        DO 2 I=1,NCOEF
        STR=G3(I)
        DO 4 J=1,NDV
        DELT(J)=XX(J)-X(J)
        STR=STR + GRDG1(J,I)*DELT(J)
4       CONTINUE
        G(I)=STR
2       CONTINUE
C
C   FREQUENCIES
C
        DO 6 I=1,NMODE
        EIG=G1(I)
        DO 8 J=1,NDV
        DELT(J)=XX(J)-X(J)
        EIG=EIG+GRDG2(J,I)*DELT(J)
8       CONTINUE
        FREQ(I)=EIG
6       CONTINUE
C
C   EIGENMODES
C
        DO 10 I=1,N1
        VEC=G2(I)
        DO 12 J=1,NDV
        DELT(J)=XX(J)-X(J)
        VEC=VEC+GRDG(J,I)*DELT(J)
12      CONTINUE
        VECN(I)=VEC
10      CONTINUE
        ID=0
        DO 14 I=1,NMODE
        DO 16 J=1,NNODE
        DO 17 K=1,3
        ID=ID+1
        AMODE(I,K,J)=VECN(ID)
17      CONTINUE
16      CONTINUE
14      CONTINUE
        DO 21 K=1,NMODE
        DO 20 I=1,NSNODE
        IF(INN.LE.3)THEN
        WRITE(3,1000)(AMODE(K,J,NODE(I)),J=1,3)
1000    FORMAT(3E15.8)
```

```
      GO TO 19
      ENDIF
      IF(INN.LE.6)THEN
      WRITE(4,1000)(AMODE(K,J,NODE(I)),J=1,3)
      GO TO 19
      ENDIF
      IF(INN.LE.9)THEN
      WRITE(8,1000)(AMODE(K,J,NODE(I)),J=1,3)
      ENDIF
19    CONTINUE
20    CONTINUE
21    CONTINUE
      IJ=(INN-1)*NMODE
      DO 50 IK=1,NMODE
      IJK=IJ+IK
50    S1(IJK)=FREQ(IK)
      IL=(INN-1)*NCOEF
      DO 51 IM=1,NCOEF
      ILM=IL+IM
51    S2(ILM)=G(IM)
30    CONTINUE
      JP=0
      DO 52 J=1,NLIM2
      DO 53 I=1,NELT
      DO 54 K=1,1
      JP=JP+1
      STRS(I,J,K)=S2(JP)
54    CONTINUE
53    CONTINUE
52    CONTINUE
      IC=NLIM2/18
      DO 61 IZ=1,54
61    DD(IZ)=0.01
      DO 60 I=1,IC
      WRITE(7,*)((GMAS(II,J),J=1,18),II=1,18)
      KP=(I-1)*18
      WRITE(7,*)(S1(KP+II),II=1,18)
      DO 55 IEL=1,NELT
      DO 56 K=1,1
      WRITE(7,*)(STRS(IEL,IY,K),IY=KP+1,KP+18)
56    CONTINUE
55    CONTINUE
      WRITE(7,*)(DD(IZ),IZ=1,18)
60    CONTINUE
      STOP
      END
 EOI ENCOUNTERED.
/
```

```
LIST,FN=GRAD
      PROGRAM GRAD(DECIS,ITER,GRDATA,CONDAT,SECPROP,FLAG,OBDJ,
     *TAPE31=DECIS,TAPE30=ITER,TAPE32=GRDATA,TAPE22=CONDAT,
     *TAPE7=SECPROP,TAPE14=FLAG,TAPE2=OBDJ)
C
C ******************************************************
C
C  THIS PROGRAM IS A PREPROCESSOR TO A GRADIENT COMPUTING
C  SEGMENT - GRADIENTS OF EIGENVALUES, EIGENVECTORS AND
C  STRESS COEFFICIENTS ARE COMPUTED
C
C  PRABHAT HAJELA, JUNE 1985
C
C ******************************************************
C
      DIMENSION GRDG(8,1500),GRDOBJ(10),X(10),G1(100)
     *,G2(13000),G3(10000),G4(10),Y(10)
     *,GRDG1(8,1100),GRDG2(8,10)
      NMODE=6
      ND41=10
      NSTR=72
      NDOF=240
      NCOEF=NSTR*NMODE
      OPEN(UNIT=30,FILE='ITER')
      OPEN(UNIT=31,FILE='DECIS')
      OPEN(UNIT=7,FILE='SECPROP')
      OPEN(UNIT=22,FILE='CONDAT')
      READ(30,*)ITER,NDV
      REWIND 30
C
C READ DESIGN VARIABLES AND FINITE DIFFERENCE STEP SIZE
C
      READ(31,*)(X(I),I=1,NDV),(Y(I),I=1,ND41),FDCH
      ITER=ITER+1
C
C
C IF ITER.EQ.NDV+1 THEN ALL DV'S PERTURBED
C
      IF(ITER.EQ.NDV+1)GO TO 100
      IF(ITER.GE.1)X(ITER)=X(ITER)*(1.+FDCH)
C
C WRITE SPAR INPUT RUNSTREAM
C
      REWIND 7
      WRITE(7,98)
98    FORMAT('[XQT TAB',/,'BC')
      DO 1 I=1,NDV
      WRITE(7,*)I,X(I)
1     CONTINUE
      WRITE(7,99)
99    FORMAT('SA')
      DO 2 I=1,ND41
      WRITE(7,*)I,Y(I)
```

```
2       CONTINUE
        WRITE(7,1010)
1010    FORMAT('[XQT EXIT')
        REWIND 7
        WRITE(30,*)ITER,NDV
        GOTO 110
100     CONTINUE
C
C   COMPUTE GRADIENTS
C
        ITER=-1
        WRITE(30,*)ITER,NDV
        NLIM1=NDV+1
        NLIM2=NMODE*NLIM1
        NLIM3=NCOEF*NLIM1
        NLIM4=NDOF*NLIM1*NMODE
        OPEN(UNIT=32,FILE='GRDATA')
        READ(32,*)(G1(I),I=1,NLIM2),
       *(G2(I),I=1,NLIM4),
       *(G3(I),I=1,NLIM3),
       *(G4(I),I=1,NLIM1)
C
C  OBJECTIVE
C
        DO 10 I=1,NDV
        J1=I+1
        GRDOBJ(I)=(G4(J1)-G4(1))/(FDCH*X(I))
10      CONTINUE
C
C   FREQUENCY
C
        DO 25 J=1,NDV
        II=NMODE*J
        DO 20 I=1,NMODE
        II1=II+I
        GRDG2(J,I)=(G1(II1)-G1(I))/(FDCH*X(J))
20      CONTINUE
25      CONTINUE
C
C   STRESS COEFFICIENTS
C
        DO 27 J=1,NDV
        II=NCOEF*J
        DO 22 I=1,NCOEF
        II1=II+I
        GRDG1(J,I)=(G3(II1)-G3(I))/(FDCH*X(J))
22      CONTINUE
27      CONTINUE
C
C   EIGENMODES
C
        N1=NDOF*NMODE
        DO 29 J=1,NDV
        II=N1*J
        DO 24 I=1,N1
        II1=II+I
        GRDG(J,I)=(G2(II1)-G2(I))/(FDCH*X(J))
24      CONTINUE
29      CONTINUE
C
```

```
C  WRITE GRAD INFO
C
      WRITE(22,*)(G1(I),I=1,NMODE),
     *(G2(I),I=1,N1),
     *(G3(I),I=1,NCOEF),G4(1),
     *(GRDOBJ(I),I=1,NDV),
     *((GRDG(I,J),I=1,NDV),J=1,N1),
     *((GRDG2(I,J),I=1,NDV),J=1,NMODE),
     *((GRDG1(I,J),I=1,NDV),J=1,NCOEF)
C
      REWIND 22
      OPEN(UNIT=2,FILE='OBDJ')
      WRITE(2,*)G4(1),(GRDOBJ(I),I=1,NDV)
C
C EXIT FROM GRADIENT LOOP BY DECLARING TAPE14 AS LOCAL
C
      OPEN(UNIT=14,FILE='FLAG')
      WRITE(14,*)ITER
110   CONTINUE
      STOP
      END
 EOI ENCOUNTERED.
/
```

```
LIST,FN=OBJFUN
      PROGRAM OBJFUN(DECIS,ITER,DESIGN,CVD1,CONMDT,OBDJ,
     *TAPE8=CVD1,TAPE10=DESIGN,TAPE16=CONMDT,
     *TAPE4=DECIS,TAPE7=ITER,TAPE2=OBDJ)
C
C****************************************************
C
C  THIS PROGRAM COMPUTES AND WRITES THE SENSITIVITY
C  INFORMATION AS REQUIRED BY THE OPTIMIZATION
C  PROGRAM, CONOPT.
C
C  PRABHAT HAJELA  JULY 1985
C
CC  **************************************************
C
      DIMENSION A(12000),STR(1000),STRR(1000)
      DIMENSION Y(10),X(10),XX(10),TEM(1000)
      DIMENSION GSE(1000),GFF(1000),GRDOBJ(10),GRDG(10,200)
      DATA NSTR/72/,SIGAL/25000./,TSE/6.15168E+7/,PI/3.14159/,
     *TFF/6.15168E+7/,GAM5/24./,CEE/1.E+41/,ND41/10/
      OPEN(UNIT=8,FILE='CVD1')
      OPEN(UNIT=10,FILE='DESIGN')
      OPEN(UNIT=16,FILE='CONMDT')
      OPEN(UNIT=4,FILE='DECIS')
      OPEN(UNIT=7,FILE='ITER')
      OPEN(UNIT=2,FILE='OBDJ')
      READ(7,*)ITER,NDV
      READ(2,*)OBJ1,(GRDOBJ(I),I=1,NDV)
      READ(10,*)(X(I),I=1,NDV)
      READ(4,*)(XX(I),I=1,NDV),(Y(I),I=1,ND41),FDCH
      NLIM1=NDV+1
      NLIM2=NLIM1*NSTR
      NSTR1=1 + 2*NSTR
      NSTRSQ=NSTR1**2
      NDIM=(NSTRSQ+NSTR1)/2
      READ(8,*)N1
      DO 2 IJ=1,NLIM1
      READ(8,*)N1,(A(I),I=1,NDIM)
      IN=(IJ-1)*NSTR
      JCK=1
      DO 4 I=1,NSTR1-1
      TEM(I)=SQRT(A(JCK))
      JCK=JCK+NSTR1-(I-1)
 4    CONTINUE
      DO 6 I=1,NSTR
      K=NSTR+I
      STR(I+IN)=TEM(I)
 6    STRR(I+IN)=TEM(K)
 2    CONTINUE
C
C  CONSTRAINT - SINGLE EXCURSION FAILURE
C
```

```
      DO 10 I=1,NLIM2
      STR(I)=STR(I)*100.
      STRR(I)=STRR(I)*100.
      FUN=(SIGAL**2)/(2.*STR(I)*STR(I))
      FUN=-FUN
      IF(FUN.LE.-675.0)FUN=-675.0
      IF(FUN.GE.741.0)FUN=741.0
10    GSE(I)=(TSE/PI)*(STRR(I)/STR(I))*EXP(FUN) - 1.
C
C  CONSTRAINT - FATIGUE FAILURE
C
      DO 12 I=1,NLIM2
      FUN=(TFF/(PI*CEE))*8.*GAM5
12    GFF(I)=(FUN*STRR(I)*(STR(I)**7)) - 1.
C
C  CONSTRAINT DERIVATIVES
C
      DO 14 I=1,NDV
      K=I*NSTR
      DO 16 J=1,NSTR
      GRDG(I,J)=(GSE(K+J)-GSE(J))/(FDCH*X(I))
16    CONTINUE
14    CONTINUE
      DO 18 I=1,NDV
      K=I*NSTR
      DO 20 J=NSTR+1,2*NSTR
      GRDG(I,J)=(GFF(K+J-NSTR)-GFF(J-NSTR))/(FDCH*X(I))
20    CONTINUE
18    CONTINUE
C
C  WRITE OBJECTIVE, CONSTRAINTS AND THEIR DERIVATIVES
C
      WRITE(16,*)(GSE(I),I=1,NSTR),
     *(GFF(I),I=1,NSTR),OBJ1,
     *((GRDG(I,J),I=1,NDV),J=1,2*NSTR),
     *(GRDOBJ(I),I=1,NDV)
C
      STOP
      END
 EOI ENCOUNTERED.
/
```

```
LIST,FN=POST
      PROGRAM POST(DESIGN,DECIS,ITER,TAPE2=ITER,
     *TAPE7=DECIS,TAPE8=DESIGN)
C
C ************************************************************
C
C THIS PROGRAM UPDATES THE DECIS FILE AND CAN ALSO BE USED
C TO DETERMINE IF MODES NEED TO BE RECOMPUTED IN PROBLEM
C
C  PRABHAT HAJELA JULY 1985
C
C ************************************************************
C
      DIMENSION X(10),Y(10),XX(10)
      DATA ND41/10/
      OPEN(UNIT=2,FILE='ITER')
      OPEN(UNIT=7,FILE='DECIS')
      OPEN(UNIT=8,FILE='DESIGN')
      READ(2,*)ITER,NDV
      READ(7,*)(XX(I),I=1,NDV),(Y(I),I=1,ND41),FDCH
      READ(8,*)(X(I),I=1,NDV)
      DO 2 I=1,NDV
2     XX(I)=X(I)
      REWIND 8
      REWIND 7
      WRITE(7,100)(XX(I),I=1,NDV),(Y(I),I=1,ND41),FDCH
100   FORMAT(F10.4)
      STOP
      END
 EOI ENCOUNTERED.
/
```

```
LIST,FN=REDUC
      PROGRAM REDUC(CVDATA,TAPE3=CVDATA,OUTPUT)
C
C ************************************************************
C
C  THIS PROGRAM REDUCES THE SIZE OF THE COVARIANCE MATRIX
C
CC
C  PRABHAT HAJELA  JULY 1985
C
C ************************************************************
C
      DIMENSION CV(145,145)
      OPEN(UNIT=3,FILE='CVDATA')
      READ(3,*)N1
      READ(3,*)((CV(I,J),J=1,N1),I=1,N1)
      REWIND 3
      WRITE(3,*)N1
      DO 2 I=1,N1
      WRITE(3,*)(CV(I,J),J=I,N1)
2     CONTINUE
      CLOSE(UNIT=3)
      STOP
      END
 EOI ENCOUNTERED.
/
```

non-repeatable part of SPAR

```
LIST,FN=NREPT
[XQT TAB
 START  80,4 5 6
 MATC
 1 10.5+6 .3 .1
 2 10.5+6 .3 .1
 JLOC
   1        0.00      -67.50       3.78
   2        0.00      -67.50       7.02
   3        0.00      -37.50      10.80
   4        0.00       -7.50      10.80
   5        0.00       22.50       7.02
   6        0.00       22.50       3.78
   7        0.00       -7.50       0.00
   8        0.00      -37.50       0.00
   9       40.00      -81.57       3.89
  10       40.00      -81.57       6.91
  11       40.00      -53.61      10.43
  12       40.00      -25.64      10.43
  13       40.00        2.32       6.91
  14       40.00        2.32       3.89
  15       40.00      -25.64       0.37
  16       40.00      -53.61       0.37
  17       80.00      -95.64       4.00
  18       80.00      -95.64       6.80
  19       80.00      -69.71      10.07
  20       80.00      -43.79      10.07
  21       80.00      -17.86       6.80
  22       80.00      -17.86       4.00
  23       80.00      -43.79       0.73
  24       80.00      -69.71       0.73
  25      120.00     -109.71       4.11
  26      120.00     -109.71       6.69
  27      120.00      -85.82       9.70
  28      120.00      -61.93       9.70
  29      120.00      -38.04       6.69
  30      120.00      -38.04       4.11
  31      120.00      -61.93       1.10
  32      120.00      -85.82       1.10
  33      160.00     -123.78       4.22
  34      160.00     -123.78       6.58
  35      160.00     -101.92       9.33
  36      160.00      -80.07       9.33
  37      160.00      -58.22       6.58
  38      160.00      -58.22       4.22
  39      160.00      -80.07       1.47
  40      160.00     -101.92       1.47
  41      200.00     -137.84       4.33
  42      200.00     -137.84       6.47
  43      200.00     -118.03       8.97
  44      200.00      -98.22       8.97
  45      200.00      -78.40       6.47
  46      200.00      -78.40       4.33
```

```
   47     200.00     -98.22        1.83
   48     200.00    -118.03        1.83
   49     240.00    -151.91        4.44
   50     240.00    -151.91        6.36
   51     240.00    -134.14        8.60
   52     240.00    -116.36        8.60
   53     240.00     -98.58        6.36
   54     240.00     -98.58        4.44
   55     240.00    -116.36        2.20
   56     240.00    -134.14        2.20
   57     280.00    -165.98        4.55
   58     280.00    -165.98        6.25
   59     280.00    -150.24        8.23
   60     280.00    -134.50        8.23
   61     280.00    -118.76        6.25
   62     280.00    -118.76        4.55
   63     280.00    -134.50        2.57
   64     280.00    -150.24        2.57
   65     320.00    -180.05        4.66
   66     320.00    -180.05        6.14
   67     320.00    -166.35        7.87
   68     320.00    -152.64        7.87
   69     320.00    -138.94        6.14
   70     320.00    -138.94        4.66
   71     320.00    -152.64        2.93
   72     320.00    -166.35        2.93
   73     360.00    -194.12        4.77
   74     360.00    -194.12        6.03
   75     360.00    -182.45        7.50
   76     360.00    -170.79        7.50
   77     360.00    -159.12        6.03
   78     360.00    -159.12        4.77
   79     360.00    -170.79        3.30
   80     360.00    -182.45        3.30
  CON 1
  ZERO 1,2,3;1, 8
   BC
1 1.567
2 .7176
3 0.1
4 1.567
5 .7178
6 .1
7 .1
8 .1
SA
1 .05
2 .052
3 .05
4 .05
5 .05
6 .052
7 .05
```

```
8 .05
9 .05
10 .0675
[XQT ELD
  E41
NSECT=1
2 10 11 3 1 2 3
NSECT=2
18 26 27 19 1 2 3
NSECT=3
34 42 43 35 1 2 3
NSECT=4
50 58 59 51 1 3 3
NSECT=5
1 9 16 8 1 2
8 16 15 7 1 2 2
NSECT=6
17 25 32 24 1 2
24 32 31 23 1 2 2
NSECT=7
33 41 48 40 1 2
40 48 47 39 1 2 2
NSECT=8
49 57 64 56 1 3
56 64 63 55 1 3 2
  NMAT=2
 NSECT= 9
    9   16   11   10
   16   15   12   11
   15   14   13   12
   17   24   19   18
   24   23   20   19
   23   22   21   20
   25   32   27   26
   32   31   28   27
   31   30   29   28
   33   40   35   34
   40   39   36   35
   39   38   37   36
   41   48   43   42
   48   47   44   43
   47   46   45   44
   49   56   51   50
   56   55   52   51
   55   54   53   52
   57   64   59   58
   64   63   60   59
   63   62   61   60
   65   72   67   66
   72   71   68   67
   71   70   69   68
   73   80   75   74
   80   79   76   75
```

```
  79   78   77   76
 NSECT=10
1 9 10 2 1 9
6 14 13 5 1 9
  E23
  NMAT=1
 NSECT= 1
1 9 1 2 2 7
6 14 1 2 2 1
NSECT=2
22 30 1 2 2 1
17 25 1 2 2 7
NSECT=3
38 46 1 2 2 1
33 41 1 2 2 7
NSECT=4
2 10 1 2 4 1
NSECT=5
18 26 1 2 4 1
NSECT=6
34 42 1 2 4 1
NSECT=7
54 62 1 3 2 1
49 57 1 3 2 7
NSECT=8
50 58 1 3 4 1
[XQT EXIT
 EOI ENCOUNTERED.
/
```

```
LIST,FN=REPT
[XQT E
 RESET G=386.
[XQT TOPO
[XQT EKS
[XQT K
[XQT INV
[XQT EIG
RESET INIT=8,NREQ=6,HIST=0
[XQT DCU
PRINT 1 VIBR EVAL
[XQT VPRT
PRINT VIBR MODE
[XQT AUS
SYSVEC;UNIT VEC
I=1;J=1,80;1.0
DEFINE UN=UNIT VEC
DEFINE DM=DEM DIAG
OBJF=XTY(UN,DM)
DEFINE V1=VIBR MODE 1 1 1,6
XDIS=UNION(V1)
[XQT GSF
SOURCE=XDIS AUS
[XQT DCU
TOC 1
[XQT EXIT
 EOI ENCOUNTERED.
/
```

repeatable part of SPAR

```
LIST,FN=SECPROP
[XQT TAB
BC
 1 1.0923
 2 .324
 3 .3
 4 .3
 5 .3
 6 .3
 7 .3
 8 .3
SA
 1 .05
 2 .05
 3 .05
 4 .05
 5 .05
 6 .05
 7 .05
 8 .05
 9 .05
 10 .065
[XQT EXIT
 EOI ENCOUNTERED.
/
```

new section properties
file created in GRAD

```
LIST,FN=TAP2G
 -2
 PHWING ONESIX
 $INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1,IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1,ISOUT=0,
  V0=8876.6,RHO0=0., DV=1.873E-9, NV=0,NG=1,
 NINT=5,RFLOW=0.,RFCUT=1.0,UU=8876.56,NVEL=1,RHO=5.716E-8,
  IFLPLT=0,IFRFPLT=1$
ALL 1 0
END
 $ACTINP $
 $SELECT NMODES=6 , NCNEW=0, NOC=1,2,3,4,5,6$
 $PLTSEL $
0
-2
MODES SEVEN TWELVE
 $INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1,IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1,ISOUT=0,
  V0=8876.6,RHO0=0., DV=1.873E-9, NV=0,NG=1,
 NINT=5,RFLOW=0.,RFCUT=1.0,UU=8876.56,NVEL=1,RHO=5.716E-8,
  IFLPLT=0,IFRFPLT=1$
ALL 1 0
END
 $ACTINP $
 $SELECT NMODES=6,NCNEW=0,NOC=7,8,9,10,11,12$
 $PLTSEL $
0
-2
MODES THIRTEEN EIGHTEEN
 $INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1,IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1,ISOUT=0,
  V0=8876.6,RHO0=0., DV=1.873E-9, NV=0,NG=1,
 NINT=5,RFLOW=0.,RFCUT=1.0,UU=8876.56,NVEL=1,RHO=5.716E-8,
  IFLPLT=0,IFRFPLT=1$
ALL 1 0
END
 $ACTINP $
 $SELECT NMODES=6,NCNEW=0,NOC=13,14,15,16,17,18$
 $PLTSEL $
0
-2
MODES NINETEEN TWENTYFOUR
 $INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1,IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1,ISOUT=0,
  V0=8876.6,RHO0=0., DV=1.873E-9, NV=0,NG=1,
```

```
 NINT=5,RFLOW=0.,RFCUT=1.0,UU=8876.56,NVEL=1,RHO=5.716E-8,
  IFLPLT=0,IFRFPLT=1$
ALL 2 0
END
 $ACTINP $
 $SELECT NMODES=6,NCNEW=0,NOC=1,2,3,4,5,6$
 $PLTSEL $
0
-2
MODES TWENTYFIVE THIRTY
 $INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1,IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1,ISOUT=0,
  V0=8876.6,RHO0=0., DV=1.873E-9, NV=0,NG=1,
 NINT=5,RFLOW=0.,RFCUT=1.0,UU=8876.56,NVEL=1,RHO=5.716E-8,
  IFLPLT=0,IFRFPLT=1$
ALL 2 0
END
 $ACTINP $
 $SELECT NMODES=6,NCNEW=0,NOC=7,8,9,10,11,12$
 $PLTSEL $
0
-2
MODES THIRTYONE THIRTYSIX
 $INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1,IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1,ISOUT=0,
  V0=8876.6,RHO0=0., DV=1.873E-9, NV=0,NG=1,
 NINT=5,RFLOW=0.,RFCUT=1.0,UU=8876.56,NVEL=1,RHO=5.716E-8,
  IFLPLT=0,IFRFPLT=1$
ALL 2 0
END
 $ACTINP $
 $SELECT NMODES=6,NCNEW=0,NOC=13,14,15,16,17,18$
 $PLTSEL $
0
-2
MODES THIRTYSEVEN FORTYTWO
 $INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1,IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1,ISOUT=0,
  V0=8876.6,RHO0=0., DV=1.873E-9, NV=0,NG=1,
 NINT=5,RFLOW=0.,RFCUT=1.0,UU=8876.56,NVEL=1,RHO=5.716E-8,
  IFLPLT=0,IFRFPLT=1$
ALL 3 0
END
 $ACTINP $
 $SELECT NMODES=6,NCNEW=0,NOC=1,2,3,4,5,6$
 $PLTSEL $
```

```
0
-2
MODES FORTYTHREE FORTYEIGHT
 $INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1,IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1,ISOUT=0,
  V0=8876.6,RHO0=0., DV=1.873E-9, NV=0,NG=1,
 NINT=5,RFLOW=0.,RFCUT=1.0,UU=8876.56,NVEL=1,RHO=5.716E-8,
  IFLPLT=0,IFRFPLT=1$
ALL 3 0
END
 $ACTINP $
 $SELECT NMODES=6,NCNEW=0,NOC=7,8,9,10,11,12$
 $PLTSEL $
0
-2
MODES FORTYNINE FIFTYFOUR
 $INPUT NM=18, NR=0, NC=0, NK=7, ISPLANE=3, C=69.58,
  NLOAD=72, IDCM=1, IAPLT=0, ISTABLE=1,IGUST=1,
  BN=.30,.65, NCOEF=5, NCOL=0,6*1, NKK=7*7,
  ICONSYS=0, NS=0, ISELECT=1, ICSACT=1, IBLOCK=2, KVAR=3,
  GL=30000., ISPECT=2, IPRINT=1,ISOUT=0,
  V0=8876.6,RHO0=0., DV=1.873E-9, NV=0,NG=1,
 NINT=5,RFLOW=0.,RFCUT=1.0,UU=8876.56,NVEL=1,RHO=5.716E-8,
  IFLPLT=0,IFRFPLT=1$
ALL 3 0
END
 $ACTINP $
 $SELECT NMODES=6,NCNEW=0,NOC=13,14,15,16,17,18$
 $PLTSEL $
0
12
 EOI ENCOUNTERED.
/
```

```
LIST,FN=TAPE31
PHWING TEST MODEL
ANYTHING
(3E15.8)
 $DLINPT NSECTNS=1,NSECTNA=1,NDF=3,NNODES=40,NNODET=40,
  IDLAT=1,NELAST=18,IPLTMS=0,
   IPRINT=0,ISYM=+1,
  NPMX=40,IPLTBOX=0,IPLTNOD=0,SCX=30.,SCY=30.,IDCM=1,ITOC=1$
DISP -1 1
MODES 1 1
HHD 1 1
SPLINE 1 1
END
1 40 1 0. 0. 1.
1 48 1
      67.5000     0.0000     1     3    -5     4
      37.5000     0.0000     2     3    -5     4
       7.5000     0.0000     3     3    -5     4
     -22.5000     0.0000     4     3    -5     4
      81.5700    40.0000     5     3    -5     4
      53.6100    40.0000     6     3    -5     4
      25.6400    40.0000     7     3    -5     4
      -2.3200    40.0000     8     3    -5     4
      95.6400    80.0000     9     3    -5     4
      69.7100    80.0000    10     3    -5     4
      43.7900    80.0000    11     3    -5     4
      17.8600    80.0000    12     3    -5     4
     109.7100   120.0000    13     3    -5     4
      85.8200   120.0000    14     3    -5     4
      61.9300   120.0000    15     3    -5     4
      38.0400   120.0000    16     3    -5     4
     123.7800   160.0000    17     3    -5     4
     101.9200   160.0000    18     3    -5     4
      80.0700   160.0000    19     3    -5     4
      58.2200   160.0000    20     3    -5     4
     137.8400   200.0000    21     3    -5     4
     118.0300   200.0000    22     3    -5     4
      98.2200   200.0000    23     3    -5     4
      78.4000   200.0000    24     3    -5     4
     151.9100   240.0000    25     3    -5     4
     134.1400   240.0000    26     3    -5     4
     116.3600   240.0000    27     3    -5     4
      98.5800   240.0000    28     3    -5     4
     165.9800   280.0000    29     3    -5     4
     150.2400   280.0000    30     3    -5     4
     134.5000   280.0000    31     3    -5     4
     118.7600   280.0000    32     3    -5     4
     180.0500   320.0000    33     3    -5     4
     166.3500   320.0000    34     3    -5     4
     152.6400   320.0000    35     3    -5     4
     138.9400   320.0000    36     3    -5     4
     194.1200   360.0000    37     3    -5     4
     182.4500   360.0000    38     3    -5     4
     170.7900   360.0000    39     3    -5     4
     159.1200   360.0000    40     3    -5     4
 EOI ENCOUNTERED.
/
```

```
LIST,FN=TAPE32
PHWING TEST MODEL
ANYTHING
(3E15.8)
 $DLINPT NSECTNS=1,NSECTNA=1,NDF=3,NNODES=40,NNODET=40,
  IDLAT=1,NELAST=6,IPLTMS=0,
   IPRINT=0,ISYM=+1,
  NPMX=40,IPLTBOX=0,IPLTNOD=0,SCX=30.,SCY=30.,IDCM=1,ITOC=1$
DISP -1 2
MODES 2 2
HHD 2 2
SPLINE 2 2
END
1 40 1 0. 0. 1.
1 48 1
      67.5000     0.0000      1      3     -5      4
      37.5000     0.0000      2      3     -5      4
       7.5000     0.0000      3      3     -5      4
     -22.5000     0.0000      4      3     -5      4
      81.5700    40.0000      5      3     -5      4
      53.6100    40.0000      6      3     -5      4
      25.6400    40.0000      7      3     -5      4
      -2.3200    40.0000      8      3     -5      4
      95.6400    80.0000      9      3     -5      4
      69.7100    80.0000     10      3     -5      4
      43.7900    80.0000     11      3     -5      4
      17.8600    80.0000     12      3     -5      4
     109.7100   120.0000     13      3     -5      4
      85.8200   120.0000     14      3     -5      4
      61.9300   120.0000     15      3     -5      4
      38.0400   120.0000     16      3     -5      4
     123.7800   160.0000     17      3     -5      4
     101.9200   160.0000     18      3     -5      4
      80.0700   160.0000     19      3     -5      4
      58.2200   160.0000     20      3     -5      4
     137.8400   200.0000     21      3     -5      4
     118.0300   200.0000     22      3     -5      4
      98.2200   200.0000     23      3     -5      4
      78.4000   200.0000     24      3     -5      4
     151.9100   240.0000     25      3     -5      4
     134.1400   240.0000     26      3     -5      4
     116.3600   240.0000     27      3     -5      4
      98.5800   240.0000     28      3     -5      4
     165.9800   280.0000     29      3     -5      4
     150.2400   280.0000     30      3     -5      4
     134.5000   280.0000     31      3     -5      4
     118.7600   280.0000     32      3     -5      4
     180.0500   320.0000     33      3     -5      4
     166.3500   320.0000     34      3     -5      4
     152.6400   320.0000     35      3     -5      4
     138.9400   320.0000     36      3     -5      4
     194.1200   360.0000     37      3     -5      4
     182.4500   360.0000     38      3     -5      4
     170.7900   360.0000     39      3     -5      4
     159.1200   360.0000     40      3     -5      4
 EOI ENCOUNTERED.
/
```

```
LIST,FN=TAPE33
PHWING TEST MODEL
ANYTHING
(3E15.8)
 $DLINPT NSECTNS=1,NSECTNA=1,NDF=3,NNODES=40,NNODET=40,
  IDLAT=1,NELAST=6,IPLTMS=0,
   IPRINT=0,ISYM=+1,
  NPMX=40,IPLTBOX=0,IPLTNOD=0,SCX=30.,SCY=30.,IDCM=1,ITOC=1$
DISP -1 3
MODES 3 3
HHD 3 3
SPLINE 3 3
END
1 40 1 0. 0. 1.
1 48 1
      67.5000     0.0000     1      3     -5      4
      37.5000     0.0000     2      3     -5      4
       7.5000     0.0000     3      3     -5      4
     -22.5000     0.0000     4      3     -5      4
      81.5700    40.0000     5      3     -5      4
      53.6100    40.0000     6      3     -5      4
      25.6400    40.0000     7      3     -5      4
      -2.3200    40.0000     8      3     -5      4
      95.6400    80.0000     9      3     -5      4
      69.7100    80.0000    10      3     -5      4
      43.7900    80.0000    11      3     -5      4
      17.8600    80.0000    12      3     -5      4
     109.7100   120.0000    13      3     -5      4
      85.8200   120.0000    14      3     -5      4
      61.9300   120.0000    15      3     -5      4
      38.0400   120.0000    16      3     -5      4
     123.7800   160.0000    17      3     -5      4
     101.9200   160.0000    18      3     -5      4
      80.0700   160.0000    19      3     -5      4
      58.2200   160.0000    20      3     -5      4
     137.8400   200.0000    21      3     -5      4
     118.0300   200.0000    22      3     -5      4
      98.2200   200.0000    23      3     -5      4
      78.4000   200.0000    24      3     -5      4
     151.9100   240.0000    25      3     -5      4
     134.1400   240.0000    26      3     -5      4
     116.3600   240.0000    27      3     -5      4
      98.5800   240.0000    28      3     -5      4
     165.9800   280.0000    29      3     -5      4
     150.2400   280.0000    30      3     -5      4
     134.5000   280.0000    31      3     -5      4
     118.7600   280.0000    32      3     -5      4
     180.0500   320.0000    33      3     -5      4
     166.3500   320.0000    34      3     -5      4
     152.6400   320.0000    35      3     -5      4
     138.9400   320.0000    36      3     -5      4
     194.1200   360.0000    37      3     -5      4
     182.4500   360.0000    38      3     -5      4
     170.7900   360.0000    39      3     -5      4
     159.1200   360.0000    40      3     -5      4
 EOI ENCOUNTERED.
/
```

```
LIST,FN=TAPEST
PHWING TEST MODEL
 $DLATINP ACAP=22500.0,REFCHD=69.44,
  FMACH=.700,
   NDELT=1,NP=1,NB=0,NRF=7,RFREQ=0.0,0.05,0.15,0.30,0.5,0.75,1.05,
   NSTRIP=12,NSV=0,NBV=0,NMODES=18,NDATA=0,
   NELAST=18,REFSPN=1.0,NBOX=48,NSNC=65,
   XZERO=-22.5,NR=0,
   NC=0,IDCM=1,ITOC=1  $
HHD 1 0
AERO 1 1
AIC 0 1
END
-22.5 67.5 159.12 194.12 0.0 360.0
7.02 69.51  13 5 1.0
0.0 0.25 0.5 0.75 1.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.666 0.732 0.798 0.864 0.93 1.0
1 4 5 8 9 12 13 16 17 20 21 24
25 28 29 32 33 36 37 40 41 44 45 48
SECOND CASE
 $DLATINP ACAP=22500.0,REFCHD=69.44,
  FMACH=.700,
   NDELT=1,NP=1,NB=0,NRF=7,RFREQ=0.0,0.05,0.15,0.30,0.5,0.75,1.05,
   NSTRIP=12,NSV=0,NBV=0,NMODES=18,NDATA=0,
   NELAST=18,REFSPN=1.0,NBOX=48,NSNC=65,
   XZERO=-22.5,NR=0,
   NC=0,IDCM=1,ITOC=2  $
HHD 2 0
AERO 2 2
AIC 1 0
END
-22.5 67.5 159.12 194.12 0.0 360.0
7.02 69.51  13 5 1.0
0.0 0.25 0.5 0.75 1.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.666 0.732 0.798 0.864 0.93 1.0
1 4 5 8 9 12 13 16 17 20 21 24
25 28 29 32 33 36 37 40 41 44 45 48
THIRD CASE
 $DLATINP ACAP=22500.0,REFCHD=69.44,
  FMACH=.700,
   NDELT=1,NP=1,NB=0,NRF=7,RFREQ=0.0,0.05,0.15,0.30,0.5,0.75,1.05,
   NSTRIP=12,NSV=0,NBV=0,NMODES=18,NDATA=0,
   NELAST=18,REFSPN=1.0,NBOX=48,NSNC=65,
   XZERO=-22.5,NR=0,
   NC=0,IDCM=1,ITOC=3  $
HHD 3 0
AERO 3 3
AIC 1 0
END
-22.5 67.5 159.12 194.12 0.0 360.0
7.02 69.51  13 5 1.0
0.0 0.25 0.5 0.75 1.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.666 0.732 0.798 0.864 0.93 1.0
1 4 5 8 9 12 13 16 17 20 21 24
25 28 29 32 33 36 37 40 41 44 45 48
 EOI ENCOUNTERED.
/
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15. Supplementary Notes

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16. Abstract

The present work is a first step towards establishing an optimization capability for sizing airframe structures that are subjected to a combination of deterministic and random flight loads. The random vibration environment introduces the need for selecting a statistical process that best describes the random loads and permits computation of the dynamic response parameters of interest. Furthermore, it requires a formulation of design constraints that would minimize the conservativeness in the design and retain computational viability. In the present work, the random loads are treated as a stationary, homogeneous process with a Gaussian probability distribution. This report discusses the formulation of the analysis problem, the structure of the optimization programming system and a representative numerical example.

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