

DESIGN SPECTRUM ANALYSIS IN NASTRAN

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INTRODUCTION

The utility of Design Spectrum Analysis is to give a mode by mode characterization of the behavior of a design under a given loading. The theory of design spectrum is discussed after operations are explained. User instructions are taken up here in three parts: Transient Preface, Maximum Envelope Spectrum, and RMS Average Spectrum followed by a Summary Table. A single DMAP ALTER packet will provide for all parts of the design spectrum operations.

The starting point for getting a modal break-down of the response to acceleration loading is the Modal Transient rigid format. After eigenvalue extraction, modal vectors need to be isolated in the full set of physical coordinates (P-sized as opposed to the D-sized vectors in RF 12). After integration for transient response the results are scanned over the solution time interval for the peak values and for the times that they occur. A module called SCAN was written to do this job, that organizes these maxima into a diagonal output matrix. The maximum amplifier in each mode is applied to the eigenvector of each mode which then reveals the maximum displacements, stresses, forces and boundary reactions that the structure will experience for a load history, mode by mode. The standard NASTRAN output processors have been modified for this task. It is required that modes be normalized to mass.

As such these modes can be averaged by root mean squares giving results which are entirely properties of the structure. The point to be made here is that if modes were normalized to the deflection of a point, the relationship from one mode to another would be artificially distorted by an arbitrary external influence. Conversely, the setting of modal mass to unity is in effect saying that the mass of the system remains constant and the participation of mass in each mode sums to the same value as other modes.

Rms averages are available for displacements in translation and rotation in any one of the six at a time. Taking rms averages of stresses depends on defining the type of stress in each element. The means of defining stresses is available in existing NASTRAN code in the XYPLOT module. Paths for routing the user request to this module and having it interpreted by the RMS module were established via the "frames" section of the XYPLOT command while case control is called on to prescribe a set containing all elements. Consequently, only one type of stress per element is permissible in taking rms averages; however, every element can be represented by a type of stress as different or as like its neighbor as the analyst chooses. Rms averages taken of mass normalized modes are independent of the load and are properties only of the structure. To get an rms representation of the response to loading, it becomes a simple task of multiplying the rms average by the matrix of maximum responses or by the matrix of response time histories. Control of the amount of output information is set up in partnership between switching parameters and case control. The effect is to allocate specific duties to each subcase

and to limit the number of subcases to three. Subcase 1 regulates the modal transient solution in the usual way plus it contains the specifications for output sets of displacements, stresses, forces, and constraints from the modal maxima. Subcase 2 has the sole duty of calling for ELSTRESS in all elements. Subcase 3 is reserved for setting up the modes for which rms responses are wanted.

The bulk of control is vested in 19 parameters which the user turns on or off in the PARAM section of bulk data. One of the factors that determined the design of algorithms was the desire to avoid the creation of any new bulk data cards. Using parameters helped the implementation of this policy, because PARAM is a standard bulk data card that is open-ended as far as the name and value are concerned so the IFP module treats PARAM cards with new seismic names in a routine fashion.

Transient Preface

A modal transient is started as in Modal Seismic Transient Analysis. A reference point is set up with PARAM GRDPNT; however no scaffold point is necessary because there will be no attempt to recover absolute response in design spectrum. Component directions of accelerations are indicated by assigning the appropriate set ID's of DAREA cards on PARAM NRTID# entries. Acceleration histories are put on TABLED1 cards either manually or with the use of the preprocessor TBLGEN. The user must set up the dynamic loading with the usual TLOAD and DLOAD cards. All base points must be gathered into an SPC set. Options ARFIN, QRFIN, AND URFIN are excluded from use in design spectrum analysis. Integration and output time increments need to be set up with a TSTEP card. The normalization on the EIGR card must be set to MASS.

Design Spectrum parameters have no defaults, so the user is obliged to indicate all of his intentions by evaluating every parameter. See the summary table at the end of this section for a review of these parameters. Positive values of parameters enable an option while negative values disable options.

Maximum Envelope Spectrum

After an eigenvalue analysis the modes are normalized to mass. The transient response is determined from a Modal Seismic Transient or a regular modal transient analysis and its solution is examined for the maximum displacement in every mode and each mode is rescaled according to its maximum time response. This gives the maximum deformation that a mode will see from a given load over a forcing interval. With a mode deformed to its maximum extent, it can be examined for the magnitudes of boundary forces, element stresses, and element forces that develop in it. This part of the analysis gives a spatial set of properties mode by mode each under every maximum deformation.

The user controls what behavior is to be computed and what data is to be listed by a combination of case control requests and by using parameters as control switches. There are three subcases with quite distinct functions.

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After the module SCAN determines the maximum amplifications for each mode and assembles them in the data block UHMAX, it can be used in various ways; e.g.

UHMAX can be output by setting PARAM AMX = +1. IF AMX = -1, SCAN composes UHMAX but does not print it.

The times at which modal maxima appear are in vector TMAX. Both its compilation and output are controlled by parameter TMX. When TMX = +1 TMAX is compiled and printed. If TMX = -1, they are suppressed.

UHMAX is used to amplify modal vectors to their maximum values giving a matrix called PHIPMAX. PHIPMAX is sent to the output processor where the recovery of three other quantities depend on it. The first subcase is used to organize requests for displacements, single point constraint forces, element forces and element stresses to be recovered from PHIPMAX. This first subcase is complete in that it contains a full complement of activity: loads, constraints, and outputs.

Maximum mode shapes PHIPMAX are computed and output without

option, but the set of points to be reported are controlled by the DISP specification in the first subcase.

The boundary forces due to maximum modal deformation are computed and output by setting parameter QMX = +1, but the set of points to be reported is controlled by SPCF in the first subcase.

Forces in finite elements due to maximum modal deformation are computed and output only by setting up an ELFORCE request in the first subcase.

Stresses in finite elements due to maximum modal deformation are computed and output only by setting up an ELSTRESS request in the first subcase.

RMS Average Spectrum

An alternative way of looking at a design is to have a single number characterize its behavior. This is obtained by computing root mean square averages (rms) for each mode when normalized to mass before any load is applied. These can be characterized as properties of the design without regard to load, because only ingredients of the structure are used to assemble these properties by normalizing to mass instead of normalizing to maximum deformation or normalizing to the deformation of a particular point. Then these rms properties can be linked to the loading through the amplifier matrix in either of two forms: maximum envelope or time history. Returning to the properties, there are several different quantities that can be averaged. This solution route will apply rms averages to modal displacements and modal stresses. Even this statement is not definitive, because displacements are of about 14 types; i.e., averages in each of 3 translational deformations, averages in each of 3 rotational deformations, averages of 3 resultant vectors of translations taken 2 at a time, averages of 3 resultant vectors of rotations taken two at a time, averages of the resultant vector of translations taken 3 at a time, and averages of the resultant vector of rotations taken 3 at a time. The options could be legion if every grid point were allowed to have different selections of the 14 types and then combined into a single average. The options given to the user in the solution, as here developed, are just 6. Every element will

have the same deformation option as all others and that choice will be limited to one of the 3 translations or one of the 3 rotations.

Options for stress averages are more varied than displacements. Every element is allowed to have a different type of stress to be called into the rms average; or all elements of the same class are allowed to have the same type of stress called into the rms average. For making the selection of stresses in elements, this seismic solution uses a feature which already exists in the XYPLOT module. This is invoked by setting up a second subcase and an X-Y plot packet. The second subcase is not complete; its only purpose is to define an ELSTRESS request that must embrace all elements without using the word ALL. The function of the X-Y plot packet is to utilize the "frames" section of the plot command statement to specify a type of stress to be recovered for every element. The specification permits one or any number of frames to be used but only the "whole" frame form of the specification can be interpreted. The minimum content of this plot packet, if paper plot is called for, is

```
OUTPUT(XYPLOT)
TCURVE=----- (8 characters or less. The mask of eight places to the
                right of = sign is read)
XYPAPLOT STRESS RESPONSE (ID of 2nd subcase) /el #(stress code), .....
CLEAR
```

The 3 lines for TCURVE, XYPAPLOT, and CLEAR must be contiguous. If PAPLOT is used, no plotter card is needed in the packet, nor is an entry of FILES = PLT2 needed on the NASTRAN card, nor is any JCL reference to a plotter needed. The RMS module interprets this plot data and will recognize a short-hand way of setting up the frames specification. If the user wants a block of elements to have a common stress code, the lowest numbered element can represent the block until the next element number starts the next block. For example if there were four types of elements in an analysis, and if the user wanted the same type of stress to be averaged for elements of a given type, then only four items would have to appear in the frames section--the lowest element id number of the first type with its stress code, the lowest element id number of the second type with its stress code, the lowest element id number of the third type with its stress code, and the lowest element id number of the fourth type with its stress code. For even greater convenience there is one predefined set which calls for the maximum stress in every element--no matter what its type. For the MAXSTRES option, the plot packet need not be defined. All that is required is to set parameter TAUR to MAXSTRES. The value TAUR = MAXSTRES is reserved for requesting the predefined set: processing of XYCDB will be bypassed. A TCURVE = MAXSTRES plot request can never be processed by module RMS.

The user is in control of whether the RMS module computes displacement averages or stress averages or both by the values given to parameters. Explanaion of the control parameters follows.

```
RMS modal displacements are computed and output if param 1 <= PHIR <= 6.
When PHIR = 1, u1 displacements are averaged.
When PHIR = 2, u2 displacements are averaged.
When PHIR = 3, u3 displacements are averaged.
When PHIR = 4, u4 rotations are averaged.
When PHIR = 5, u5 rotations are averaged.
When PHIR = 6, u6 rotations are averaged.
When PHIR <= 0, no rms averages of modal deformations are computed.
```

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Whenever PHIR > 0 the block of rms averages of mass normalized modes PHIZRMS can be output and/or passed on for further processing. When parameter PHIZR is set = +1, the matrix PHIZRMS is output.

Two parameters control RMS stress. When TAUSR is >0, rms stress averages will be computed for elements using the types of stresses specified by sets which are called by parameter TAUR.

When TAUR is given the name of an XYPLOT TCURVE stress set title, stresses due to the modal deformations in the mass normalized configuration are computed for each element according to the specifications set down by the user in the frames section of the XYPLOT command. If TAUSR \leq 0, no rms stresses are computed. NOTE!! It is necessary that the user set up an ELSTRESS request in the 2nd subcase calling for output of stresses in all elements; the RMS module demands that it look at all elements for computing rms stress averages. The entry in field 3 of PARAM TAUR is the mask of the 8 characters of TCURVE after the = sign, which implies that blanks are counted as characters.

When TAUSRMS is computed, it can be output and/or passed on for further processing. If parameter TAUSR is set = +1, the matrix TAUSRMS is output.

If the rms effect of load on displacements or stresses is wanted, there are two options: either amplify a matrix of rms averages by the matrix of maximum responses or by the matrix of response histories.

If the maximum rms averaged response amplitudes in each mode are wanted, they can be activated by setting parameter URX = +1. This causes the data blocks UHMAX and PHIZRMS to be multiplied to give the matrix UZRMSM, the rms averages of maximum modal amplitudes.

If the maximum rms averaged stress responses in each mode are wanted for a given load, the user sets parameter TAUX = +1. This causes the matrices UHMAX and TAUSRMS to be multiplied together to give the matrix TAURMSM which is sent to output.

If time histories of rms displacements or rms stresses are wanted, a third subcase must be set up. If the third subcase is included, it must be preceded by two earlier subcases. The 3rd subcase is not complete. Its sole purpose is to prescribe outputs of SDISP, or SVELOCITY, or SACCELERATION requests of mode numbers for which rms histories are wanted. Such calls to mode sets are used for either rms displacements or rms stresses or both. If only maximum amplifications of rms averages are wanted, the 3rd subcase is not needed.

If it is desired to have a time history of the rms average deflections in each mode, the user sets parameter URT = +1. This causes data blocks PHIZRMS and UHVT to be multiplied to give matrix UZRMST. If a time history of rms averaged stress responses in each mode are wanted for a given load, the user sets parameter TAUT = +1. This causes the matrices TAUSRMS and UHVT to be multiplied together to give the matrix TAURMST which is sent to output. If plots of UZRMST or TAURMST are wanted, the necessary entries are made in the XYPLOT packet. The plot command statement is distinct from that used for specifying element stress types and it must refer to the 3rd subcase for control of what modes are to be plotted.

DESIGN SPECTRUM

Summary Table of Control Options for DESIGN SPECTRUM

Quantity to be Computed	Matrix Name	Control		Module Where	
		Compute	Output	Computed	Output
		Param/S-C	Param/S-C		
Max Modal Amplitudes	UHMAX	Automatic	AMX	SCAN	MDLOFP
Time of Max Modal Amp	TMAX	TMX	TMX	SCAN	MDLOFP
Mode Shapes in Max Amplification	PHIPMAX	Automatic	1st S-C	MPYAD	OFPS
SPC Forces in Max Amplification	QPHMAX	QMX	1st S-C	MPYAD	OFPS
El Stresses in Max Amplification	IESMAX	1st S-C	1st S-C	SDR2	OFPS
Element Forces in Max Amplification	IEFMAX	1st S-C	1st S-C	SDR2	OFPS
RMS Avg of Mass Norm- alized Mode Shapes	PHIZRMS	PHIR	PHIZR	RMS	MDLOFP
RMS Avg of Max Defl Response to Load	UZRMSM	URX	URX	MPYAD	MDLOFP
RMS Avg Time History Defl Resp to Load	UZRMST	URT	URT/ 3rd S-C	MPYAD	OFPS
Stress Types for each Element	Parameter TAUR	FRAMES section of XYPLOT		XYPLOT	XYCDB
RMS Avg of Mass Norm- alized El Stresses	TAUSRMS	TAUR/ 2nd S-C	TAUSR	RMS	MDLOFP
RMS Avg of Max Stress Response to Load	TAURMSM	TAUX	TAUX	MPYAD	MDLOFP
RMS Avg Time History Stress Resp to Load	TAURMST	TAUT	TAUT/ 3rd S-C	MPYAD	OFPS

THEORY

Maximum Envelope Spectrum

The transient response by the modal method rests on the principle of summing the contributions of individual modes to the total response.

$$u(x,t) = \sum_{i=1} [\phi_i(x)] \{E_i(t)\} \quad (1)$$

where $\phi_i(x)$ is the shape that a structure takes while oscillating at a natural frequency i ; and $E_i(t)$ is the factor by which the i th mode shape is amplified at time 't' to represent the participation of the i th mode in the response to some loading. The total response of the structure at all locations in the structure and at all times is the summation of responses from individual modes for an infinity of modes. When fewer than infinite modes are employed, the summation gives an approximation to the true response. Many design situations are addressed in terms of maximum demands. The rationale taken is that; if a structure can meet the maximum demands, it can survive all lesser demands. This general principle has been extended to dynamic response by viewing the maximum demands, mode by mode. After finding the maximum value for $E_i(t)$ over all times, this $E_i(\max)$ is used to amplify the mode shape $\phi_i(x)$ in the i th mode. Each mode is studied in its maximum amplification for its shape envelope, its stress distributions, its boundary constraint forces, and for the distribution of elastic forces. This has been implemented for NASTRAN in the seismic analysis packet for the mode shapes $\phi_i(x)$ and frequencies ω_i and the response history $E_i(t)$.

A module called SCAN was written to search through all modal accelerations \ddot{E}_i , modal velocities \dot{E}_i , and modal displacements E_i and to catalog the maximum of modal displacement, only, in each mode and organize these findings of maximum displacement amplitude in a diagonal matrix of $E_i(\max)$ named UHMAX. The times of occurrence of the maxima are also catalogued in a vector named TMAX.

Each mode is amplified to its maximum and collected into a matrix named PHIPMAX

$$[\phi_i] [E_i(\max)] = [\phi_i(\max)] \quad (2)$$

The matrix of boundary constraint forces in each mode $Q_i(x)$ is also amplified to its maximum in each mode and collected into a matrix named QPMAX.

$$[Q_i(x)] [E_i(\max)] = [Q_i(\max)] \quad (3).$$

The data block PHIPMAX, representing maximum modal amplification, is delivered to the stress data recovery module to be processed for element stress and force distributions in every mode in its maximum configuration. The user can control how much of this maximum response data is printed out by indicating those elements and grid points for which he wants information by grouping their ID's into sets in Case Control. Output is handled similar to the way that Eigenvalue Analysis Rigid Format treats it.

RMS Spectrum

Another way of measuring design requirements is to characterize structural response in terms of its root mean square (RMS) property. RMS is so general a term that it could mean many different things to many different people. Consequently, it is necessary to be specific as to what property is being described in terms of its RMS value. This discussion will branch into two topics: mode shapes and stresses.

A mode shape is described in terms of its 3 translational and its 3 rotational displacements. An rms average of all six displacements is not meaningful, because rotations and displacements are measured in two different dimensions, lengths and radians. An rms average of translations only or an rms average of rotations only is more meaningful than a mixture. When triggered by a parameter, indicating which one of the six displacements is to be used, the RMS module partitions that one component of the mode shapes at every point 'p' in the structure where the mode is defined. Let 'z' stand for any of the 3 translations or rotations and let $\phi_i(z)$ be the partition of the zth displacements in

the ith mode at the N grid points, then this rms computation is carried out:

$$\phi_i^{rms}(z) = \left[\frac{1}{N} \sum_{p=1}^N [\phi_i(z)]_p^2 \right]^{1/2} \quad (4)$$

$\phi_i^{rms}(z)$ is interpreted as the rms value of z displacements in the ith mode. The RMS module carries out these average computations for all "i" modes and organizes the results in a diagonal matrix.

$$[\phi_i^{rms}(z)]$$

Only the mode shapes are involved in this computation, but the values computed depend upon the method of normalizing mode shapes. If modes are normalized to mass a truly consistent method of interpreting, the rms values is achieved. An rms value of a mass normalized mode is a property of the structure and can have meaning to a structural designer. Having rms properties of modes, one can use these to make

interpretations of responses. Amplifying the rms averaged modes by the

matrix of time varying amplitudes $[E_i(t)]$ can be called the rms time varying response of a loading in the chosen z component.

$$[U^{rms}(z,t)] = [\varphi_i^{rms}(z)] [E_i(t)] \quad (5)$$

$U^{rms}(z,t)$ is interpreted as the rms weighted time response of a structure to a load in component z.

Amplifying the rms averaged modes by the envelope of maximum responses gives a kind of rms of peaks in the chosen component.

$$[\varphi_i^{rms}(z_{max})] = [\varphi_i^{rms}(z)] [E_i(max)] \quad (6)$$

The advantage of this rms of peaks is that one number per mode characterizes the response of the system.

Stress at a point is described in terms of a tensor, but the dimension of every stress is the same; i.e., force per unit area. In some part of a structure, one type of stress such as bending may dominate while in another part the dominant type of stress may be shear and in yet another part axial stress may be dominant and so on. The RMS module will allow the user to be specific about which type of stress he wants to designate for each individual element throughout the whole structure to characterize the average stress behavior. Only one type of stress at only one location in any one element may be chosen; e.g., there are 21 stress options for the CIHEX1 element but only one of these 21 may be selected for an element. Call the stress reading in the ith mode $S_i(s)$.

Lower case 's' is the set number of the prescribed stress types at each element over a total of 'n' elements, and let i represent the ith mode. Call the stress reading in the mass normalized ith mode $S_i(s)$, composed

of the stress types in set 's' involving the 'n' elements that were used to model the structure. The rms computation that is carried out for the ith mode is:

$$\zeta_i^{rms}(s) = \left[\frac{1}{n} \sum_{e=1}^n [S_i(s)]_e^2 \right]^{1/2} \quad (7)$$

The RMS module carries out these average computations for all 'i' modes and organizes the results in a diagonal matrix.

$$[\zeta_i^{rms}(s)].$$

Only mode shapes in their normalized deformation were involved in this calculation, so these averages can be considered to be properties of the structure for the 's' combination of stresses. As was done with the rms

displacements, one can characterize the response of the structure under transient load in terms of these rms stress properties.

$$[\sigma_i^{rms}(s,t)] = [\sigma_i^{rms}(s)] [\xi_i(t)]. \quad (8)$$

Equation (8) represents the rms response time history of stresses in a structure for stress types according to set 's' under a given load.

Once again, a single number to characterize the design mode by mode is possible by amplifying the rms averaged stresses in modes by the envelope of maximum responses. It gives the rms of peak stresses in the chosen stress set 's' for a structure under a given load.

$$[\sigma_i^{rms}(s_{max})] = [\sigma_i^{rms}(s)] [\xi_i(\max)]$$

The Design Spectrum Rigid Format limits the user to one choice of 'z' for rms mode shape calculations and to one choice of 's' for rms stress calculations in any one run.

SOLNDS

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***** SEIRES *****
$
$
***** THESE ARE DMAP ALTERS FOR SEIRES *****
***** PERTAINING TO RIGID FORMAT DMAP *****
***** SERIES APR 82 *****

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DESIGN SPECTRUM

\$PARAMETER DEFINITIONS:

```

$
$NRTID1,2,3 = SET ID'S TO BE ASSIGNED TO DAREA CARDS REPRESENTING THE
$ SPATIAL ARRANGEMENT OF TRANSLATIONAL ACCELERATION IN THE THREE
$ COORD DIRECTIONS.
$NRTID4,5,6 = SET ID'S TO BE ASSIGNED TO DAREA CARDS REPRESENTING THE
$ SPATIAL ARRANGEMENT OF ROTATIONAL ACCELERATION IN THE THREE
$ COORD DIRECTIONS.
$AMX = CONTROL PARAMETER FOR THE OUTPUT OF THE UHMAX MATRIX.
$TMX = CONTROL PARAMETER FOR THE COMPUTATION AND OUTPUT MATRIX TMAX.
$OUTPUT CONTROL MATRIX PHIPMAX IS BY CASECC IN S/C 1 UNDER DISP=().
$QMX = CONTROL PARAMETER FOR THE COMPUTATION OF THE QPHMAX MATRIX. OUT-
$ PUT CONTROL OF MATRIX QPHMAX IS BY CASECC IN S/C 1 UNDER SPCF=().
$THE COMPUTATION AND OUTPUT OF THE ESMAX MATRIX IS UNDER THE CONTROL
$ OF ELSTRESS IN SUBCASE 1 OF CASE CONTROL
$THE COMPUTATION AND OUTPUT OF THE EFMAX MATRIX IS UNDER THE CONTROL OF
$ ELFORCE IN SUBCASE 1 OF CASE CONTROL
$PHIR = PARAMETER FOR THE COMPONENT SELECTION OF THE PHIZRMS MATRIX.
$URT = CONTROL PARAMETER FOR THE COMPUTATION OF MATRIX UZRMST. OUTPUT IS
$SELECTED BY SVEC OR SDISP OR SVELO OR SACCEL IN S/C 3 OF CASECC.
$URX = CONTROL PARAMETER FOR THE COMPUTATION AND OUTPUT OF MATRIX UZRMST.
$TAUR = CONTROL PARAM FOR THE STRESS SET SELECTION OF THE TAUSRMS MATRIX.
$TAUT = CONTROL PARAMETER FOR THE COMPUTATION OF THE TAURMST MATRIX. OUT-
$PUT IS SELECTED BY SVEC OR SDISP OR SVELO OR SACCEL IN S/C 3 OF CASECC.
$TAUX = CONTROL PARAM FOR THE COMPUTATION AND OUTPUT OF MATRIX TAURMST.
$PHIZR = CONTROL PARAMETER FOR THE OUTPUT OF THE PHIZRMS MATRIX.
$TAUSR = CONTROL PARAMETER FOR THE OUTPUT OF TAUSRMS

```

```

$*****
$
$ THE USER MUST USE MASS NORMALIZATION ON THE EIGR CARD *
$ THE USER MUST USE SUBCASE 1 FOR DLOAD AND MAX MODAL RESPONSE *
$ THE USER MUST USE SUBCASE 2 FOR MODAL RMS STRESS CALCULATIONS *
$ XYPLOT FOR SELECTION OF STRESS COMPONENTS FOR RMS *
$ THE USER MUST USE SUBCASE 3 FOR LOAD AMPLIFYING OF RMS AVERAGES *
$
$*****

```

\$\$SECTION A

```

$
ALTER 49 $ JUST BEFORE MCE
PARAM // *NOT*/SEISLD/SINGLE $
COND SYMX, SEISLD $
JUMP FINIS $
LABEL SYMX $

```

SOLNDS

\$\$ CALL IN RBTM AT THIS POINT.

\$
 RBTM BGPDT, CSTM, EGEXIN, MGG, USET/HAICH, MSEIS, , HL6/C, Y, GRDPNT/-1/
 MODAL \$

\$
 \$\$GET THE MASS AND STIFFNESS MATRICES READY FOR LOAD AND BASE FORCE
 \$\$RECOVERY.

\$\$
 VEC USET/GXVEC/*G*/*COMP*/*SB* \$ X=SB, COMP, G
 VEC USET/GYVEC/*G*/*COMP*/*R* \$ 1'S ON R
 ADD GXVEC, GYVEC/GCVEC/ \$ 1'S ON SB & R

\$-----INERTIA MATRICES-----**

PARTN MSEIS, , GCVEC/MSIZC, MSIZRB, , /5/0 \$
 ADD MSIZC, /MMSIZC/(-1.0,0.0) \$
 MERGE MMSIZC, MSIZRB, , , GCVEC/MSIZ/5/0 \$

\$
 NRTS MSIZ, DYNAMICS, EGEXIN/NRTSEIS/C, Y, DEPOP/C, Y, NRTID1/
 C, Y, NRTID2/C, Y, NRTID3/C, Y, NRTID4/C, Y, NRTID5/C, Y, NRTID6 \$

EQUIV NRTSEIS, DYNAMICS/SEISLD \$

\$\$ THE 'DYNAMICS' DATA BLOCK NOW HAS DAREA CARDS IN IT FOR THE INER-
 \$\$ TIA LOAD AND IS READY TO BE PASSED TO DPD FOR SETTING UP THE LOAD
 \$\$ ON THE RELATIVE X COORDS. IT CONTAINS DAREA NOT JUST FOR THE BASE
 \$\$ MOTION BUT FOR DIRECTLY APPLIED LOAD AS WELL. RF12 CAN NOW PROCEED
 \$\$ WITH CONDENSATION FROM X-SIZE TO A-SIZE AND DEVELOP MODAL VECTORS
 \$\$ FOR SOL'N IN TRD.

\$ \$ \$ S C A N \$ \$ \$

ALTER 102,126 \$ AFTER TRD
 \$\$\$ KEEP SDR1 # 127
 ALTER 128,144 \$ ELIMINATE THRU REPT.

\$\$\$\$ USE S/C 1 FOR TRANSIENT LOAD AND FOR SCAN OUTPUT OF MAXIMA
 SCAN UHVT, TOL/UHMAX, TMAX/C, Y, TMX \$
 MPYAD PHIPH, UHMAX, /PHIPMAX/O/+1 \$ PHIPH COMES FROM SDR1.
 \$\$\$ PHIPMAX ISSUBSEQUENTLY EMPLOYED FURTHER.

COND BOUND, QMX \$
 MPYAD QPH, UHMAX, /QPHMAX/O/+1 \$
 LABEL BOUND \$
 SDR2 CASEXX, CSTM, MPT, DIT, EQDYN, SILD, , , BGPDP, LAMA, QPHMAX, PHIPMAX,
 EST, , / , IQPHMAX, IPHIPMX, IESMAX, IEFMAX, /

MMREIG/S, N, NOSORT2 \$
 OFPS IQPHMAX, IPHIPMX, IESMAX, IEFMAX, , // \$

\$ \$ \$ R M S \$ \$ \$

\$\$\$\$ RMS AVERAGES ARE TAKEN OF DISPLACEMENTS AND STRESSES WITH RE-
 \$\$\$ SPECT TO EIGENVECTORS THAT ARE NORMALIZED TO MASS. THE USER
 \$\$\$ ASSIGNS THE COMPONENT OF MODAL DISPLACEMENT THAT HE WANTS TO SEE
 \$\$\$ AVERAGED AND INDICATES THIS ON PARAMETER "PHIR". EVERY ELEMENT
 \$\$\$ IN THE MODEL IS INCLUDED IN AN RMS STRESS AVERAGE. ONLY ONE TYPE
 \$\$\$ OF STRESS CAN BE USED PER ELEMENT. THE USER INDICATES WHICH TYPE
 \$\$\$ OF STRESS IS TO BE AVERAGED BY MAKING HIS SELECTION IN THE "FRAMES"
 \$\$\$ SECTION OF AN XYLOT COMMAND FOR S/C 2, WITH AN ASSOCIATED NAME
 \$\$\$ GIVEN ON "TCURVE". THE "TCURVE" NAME IS PUBLISHED IN PARAM "TAUR".

SOLNDS

```

PARAM      /*LE*/V, N, GOP/C, Y, PHIR/C, N, O $
PARAM      /*AND*/V, N, GOTAMP/C, Y, TAUX/C, Y, TAUT $
PARAM      /*AND*/V, N, GOTRMS/V, N, GOTAMP/C, Y, TAUSR $ GOTRMS IS INPUT
$$TO RMS IF GOTRMS IS > 0, RMS CALCULATES TAUSRMS, OR ELSE ONLY PHIZRMS.
PARAM      /*ADD*/V, N, RMS/V, N, GOP/V, N, GOTRMS $IF NEITHER PHIZRMS NOR
$$TAURMS IS WANTED, THIS IS EQUIVALENT TO SETTING PHIR, TAUX, TAUT &
$$TAUSR ALL NEGATIVE. A JUMP IS TAKEN AROUND RMS AND ENDS PROCESSING.
CASE       CASECC, /CASERR/C, N, TRAN/V, N, REPEAT/V, N, NOLOOP $
COND       NORMS, RMS $
COND       NOTAU, GOTRMS $
SDR2      CASERR, CSTM, MPT, DIT, EQDYN, SILD, , , BGPDP, LAMA, QPH, PHIPH, EST,
          XYCDB, / , , , IES1, , /*MMREIG*/S, N, NOSORT2 $
LABEL     NOTAU $
RMS       PHIPH, EQDYN, IES1, XYCDB, MHH/PHIZRMS, TAUSRMS/C, Y, PHIR/
          V, N, GOTRMS/C, Y, TAUR $
$ $ $           A   M   P   L   I   F   Y           $ $ $
$$$$$  $$$$$$  $$$$$$  $$$$$$  $$$$$$
$$ TWO DIFFERENT OPTIONS ARE EXERCISED HERE FOR AMPLIFYING THE RMS
$$ AVG MODAL PROPERTIES WITH EFFECTS OF LOAD: EITHER WITH UHMAX FOR
$$ THE RMS MAX IN EACH MODE; OR WITH UHVT FOR THE RMS HISTORIES IN
$ EA MODE IF THE USER CHOOSES THE RMS MAX INSTEAD OF A TIME HISTORY
$ OF RMS, DMAP TAKES OVER TO MULTIPY UHMAX DIAG INTO EITHER OR BOTH
$ OF THESE TO OBTAIN OUTPUT DIAG MATRICES [DOFRMSM] AND/OR [TAURMSM].
COND      UX, URX $ MAX RMS DISPLACEMENTS IN EA MODE
MPYAD     PHIZRMS, UHMAX, /UZRMST/O/+1 $
LABEL     UX $
COND      TX, TAUX $ MAX RMS STRESS IN EA MODE
MPYAD     TAUSRMS, UHMAX, /TAURMSM/O/+1 $
LABEL     TX $
PARAM     /*AND*/V, N, RAMPL/C, Y, URT/C, Y, TAUT $
PARAM     /*ADD*/V, N, REPEAT/C, N, 1/C, N, 2 $
CASE      CASECC, /CASEUU/C, N, TRAN/V, N, REPEAT/V, N, NOLOOP $
COND      NORMS, RAMPL $
$$$$$    IF THERE ARE SOME TIME DEPENDENT PARAMETERS TURNED ON, THEN
$$$$$    THE COMBINATION OF MODES FOR WHICH OUTPUT IS SELECTED IS CON-
$$$$$    TROLLED IN S/C 3 OF CASE CONTROL USING SOLUTION SET COMMANDS.
COND      UT, URT $ RMS DISPLACEMENT HISTORY IN EACH MODE
MPYAD     PHIZRMS, UHVT, /UZRMST/O/+1 $DIAG PHIZRMS INTO TRIPLET FORMAT
VDR       CASEUU, EQDYN, USETD, UZRMST, TOL, XYCDB, /OUZRMST1, /*TRANRESP*/
          *MODAL*/C, N, O/S, N, NOH/S, N, NOP/S, N, FMODE $
SDR3,    ,, OUZRMST1, , , , , , OUZRMST2, , , $ SDISP OR SVELO OR SACCEL IN
$$ %%    $$ S/C 3 CONTROLS THE OUTPUT.
OFPS     OUZRMST2, , , , , /S, N, CARDNO/S, N, OFPOPT1=-1/C, Y, PHIR/C, Y, TAUSR $
XYTRAN   XYCDB, OUZRMST2, , , , /XYPLRMSZ/*TRAN*/C, N, HSET/V, N, PFILE/
          S, N, CARDNO $
XYPLOT   XYPLRMSZ// $ XYPLOT COMMAND SHOULD SPECIFY S/C 3
LABEL    UT $
COND     TT, TAUT $ RMS STRESS HISTORY IN EACH MODE
MPYAD    TAUSRMS, UHVT, /TAURMST/O/+1 $DIAGONAL TAUSRMS INTO TRIPLET
$$$$$$$  FORMAT
VDR      CASEUU, EQDYN, USETD, TAURMST, TOL, XYCDB, /TAURMST1, /*TRANSRESP*/
          *MODAL*/C, N, O/S, N, NOH/S, N, NOP/S, N, FMODE $

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SOLNDS

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SDR3,      , , , TAURMST1, , / , , , TAURMST2, , $ SDISP OR SVELO OR SACCEL
$$  %%  $$  IN S/C 3 CONTROLS THE OUTPUT.
OFPS      TAURMST2, , , , //CARDNO/S, N, OFPOPT=-1/C, Y, PHIR/C, Y, TAUSR $
XYTRAN    XYCDB, TAURMST2, , , , /XYPLTAUR/*TRAN*/C, N, HSET/V, N, PFILE/
          S, N, CARDNO $
XYPLOT    XYPLTAUR// $ XYPLOT COMMAND SHOULD SPECIFY S/C 3
LABEL     TT $
LABEL     NORMS $
MDLOFF    LAMA, UHMAX, TMAX, PHIZRMS, UZRMSM, TAUSRMS, TAURMSM//
          C, Y, AMX/C, Y, TMX/C, Y, PHIZR/C, Y, URX/C, Y, TAUSR/C, Y, TAUX/
          C, Y, PHIR/C, Y, TAUR $
JUMP      FINIS $
ENDALTER

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