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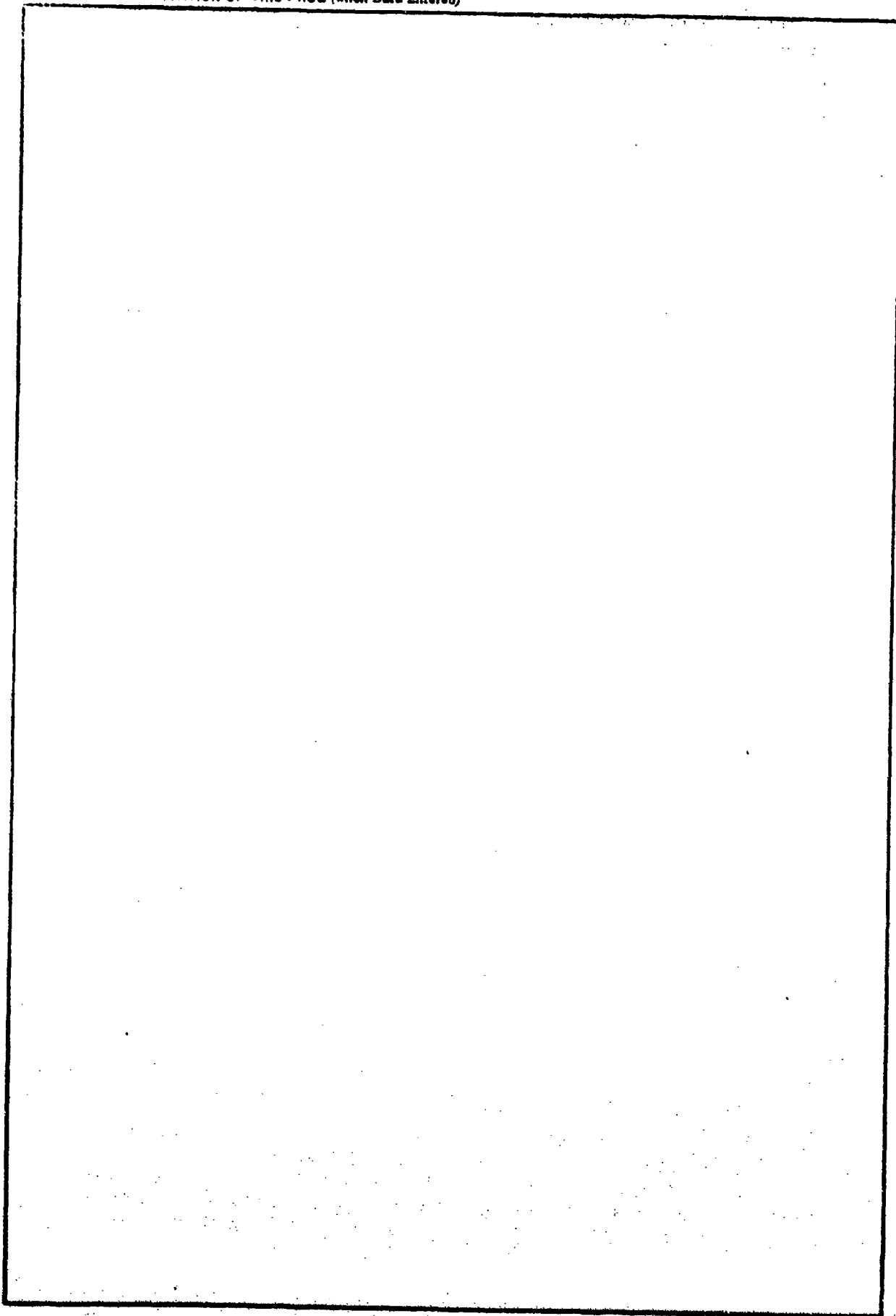
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PREFACE

This report is a replacement for the report, "The Dynamic Design-Analysis Method (DDAM) in NASTRAN," David W. Taylor Naval Ship Research and Development Center Report DTNSRDC-81/073, October 1981. The present work incorporates efficiency improvements, corrections, and additional capability into the previous work, necessitating modifications to the user specifications. This report is self-contained and does not require retention of DTNSRDC-81/073.

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ABSTRACT

This report describes the theory, implementation, and use of the Dynamic Design-Analysis Method (DDAM) in the NASTRAN finite element structural analysis computer program. DDAM is the procedure used in the shock design of shipboard equipment. Since such equipment is also frequently analyzed with NASTRAN, the inclusion of DDAM in NASTRAN greatly enhances the efficiency of the design-analysis process.

ADMINISTRATIVE INFORMATION

The work reported was performed under Task Area S0923001, Task 23350, Work Unit 1102-020.

INTRODUCTION

The Dynamic Design-Analysis Method (DDAM) is the standard procedure for shock design of shipboard equipment. Often, the equipment is first analyzed with the NASTRAN finite element structural analysis computer program.^{1*} The data and results must then be converted into other forms for use in DDAM. Incorporating DDAM into NASTRAN has enabled the entire process to be performed more efficiently. This report describes the implementation of DDAM into the DTNSRDC version of NASTRAN Level 17.5 and the input data required.

The present work was undertaken as part of an effort to develop validated structural analysis procedures in support of the Improved Performance Machinery Program, a DTNSRDC Systems Development Department project related to onboard machinery.

THEORY

The steps of the DDAM procedure are described here very briefly. A more complete description is given by Belsheim and O'Hara.² Their terminology as well as that of NASTRAN will be used in the mathematical description.

Step 1. Compute natural frequencies and mode shapes. (NASTRAN's Rigid Format 3).

Step 2. Compute the participation factor for each mode.

*A complete listing of references is given on page 19.

$$P_a = \frac{\sum_i M_i X_{ia}}{\sum_i M_i X_{ia}^2} \quad (1)$$

where M_i is the mass of the i th degree-of-freedom and X_{ia} is the i th component of the a th mode shape.

It is assumed that only those terms of $\{X_a\}$ that correspond to a particular direction are used in Equation (1). That is, the a th mode may have three participation factors associated with it, one for each orthogonal direction.

In NASTRAN terminology, the numerator of Equation (1) may be written as (considering all computed modes)

$$[\Phi]^T [M] [V] \quad (1a)$$

where $[\Phi]$ = matrix of eigenvectors (mode shapes), order $n \times m$, with n = order of the problem, m = number of modes computed

$[M]$ = mass matrix, order $n \times n$

$[V]$ = direction cosine matrix, order $n \times l$ with $l = 1, 2$, or 3 , the number of desired directions

Typically, $[V]$ may consist of 1's and 0's which "pick off" desired directions.

However, that form is not necessary and any consistent set of direction cosines may be used.

The denominator of Equation (1) may be written as (considering all computed modes)

$$[\Phi]^T [M] [\Phi] \quad (1b)$$

which is the diagonal modal mass matrix. Therefore, we may write Equation (1) as

$$[P_a]_{m \times l} = [\text{diag}([\Phi]^T [M] [\Phi])]^{-1} [\Phi]^T [M] [V] \quad (2)$$

Step 3. Compute the "effective mass" in each mode

$$M_a = P_a \sum_i M_i X_{ia} \quad (3)$$

In NASTRAN terminology,

$$[M_a]_{m \times l} = [P_a] \times [\Phi]^T [M] [V] \quad (4)$$

where the $\times$ on the right side indicates the so-called matrix outer product, in which a term-by-term multiplication is performed. For example, if

$$[C] = [A] \times [B]$$

then

$$c_{ij} = a_{ij} b_{ij}$$

Step 4. Compute the "effective weight" $[W_a]$ in each mode by multiplying $[M_a]$ by g , the acceleration due to gravity.

Step 5. Compute the direction-dependent velocity spectrum design values $[V_a]$ from $[W_a]$.

Step 6. Compute the effective static load at each mass, due to the a th mode, by

$$F_{ia} = M_i X_{ia} P_a V_a \omega_a \quad (5)$$

where ω_a is the a th natural radian frequency.

In NASTRAN, the matrix of loads is computed as follows: The matrix product $[N][\Phi]$ is of order $n \times m$ and corresponds to the product $M_i X_{ia}$ of Equation (5). (Here, only terms of $[N][\Phi]$ in the desired directions are used.) The a th column of $[N][\Phi]$ corresponds to the a th mode. Multiplying the a th column by ω_a and by $P_a V_a$

for the first desired direction gives a matrix of load vectors of order $n \times m$. If $P_a V_a$'s for other desired directions are used, then other $n \times m$ sets of loads are created and appended to the first set. A final load matrix $[F]$, of order $n \times ml$, is thus created, where l is the number of desired directions, i.e., there will be ml static load cases. (In practice, instead of the product $V_a \omega_a$ in Equation (5), the term actually used is $\min(V_a \omega_a, A_a g)$, where A_a is an acceleration spectrum design value in g's and g is the acceleration due to gravity.)

Step 7. Perform static analyses to compute direction-dependent maximum responses, using the load cases from Step 6, and calculate element stresses.

The computation of the effective static load at each mass in Step 6 and the static analyses of Step 7 may be replaced as follows: For the a th mode $\{\phi_a\}$, Equation (5) may be written

$$\{F_a\} = [M] \{\phi_a\} P_a V_a \omega_a \quad (5a)$$

Solving

$$[K] \{u_a\} = \{F_a\} \quad (5b)$$

where $[K]$ is the stiffness matrix and $\{u_a\}$ is the vector of grid point displacements, yields

$$\{u_a\} = [K]^{-1} [M] \{\phi_a\} P_a V_a \omega_a \quad (5c)$$

However, from dynamics,

$$[-\omega_a^2 M + K] \{\phi_a\} = 0 \quad (5d)$$

or

$$[K]^{-1} [M] \{\phi_a\} = \frac{1}{\omega_a^2} \{\phi_a\} \quad (5e)$$

Using Equation (5e) in Equation (5c) yields

$$\{u_a\} = \{\phi_a\} \frac{P_a V_a}{\omega_a} \quad (5f)$$

(As in Step 6, rather than V_a/ω_a , $\min(V_a/\omega_a, A_a g/\omega_a)$ is used.)

Equation (5f) is used in NASTRAN to compute the direction-dependent maximum response.

Step 8. For each of the l desired directions, compute the NRL sums of stresses³ for each element as follows:

$$S_j = |S_{jm}| + \sqrt{\sum_{b \neq m} (S_{jb})^2}$$

where S_{jm} = maximum stress at the j th point (taken over the modes under consideration in one desired direction) and S_{jb} = stresses (other than the maximum) at the j th point corresponding to the modes described for S_{jm} .

NASTRAN IMPLEMENTATION

Since DDAM requires the determination of natural frequencies and mode shapes, a NASTRAN/DDAM analysis will consist of Rigid Format 3 with ALTER's. The ALTER's required in the NASTRAN run will compute the various quantities described in the previous section. Among the ALTER's are instructions for NASTRAN to execute the following eight new functional modules which were added to the program for DDAM.

GENCOS

GENCOS generates the direction cosine matrix $[V]$ in Expression (1a). The user may specify a coordinate system which defines the shock directions. A PARAM bulk data card giving the value of parameter SHOCK passes to GENCOS the coordinate system identification number of the shock system. If the user does not include such a card, NASTRAN's basic coordinate system will be used. (The value of parameter SHOCK should, in most cases, correspond to the displacement coordinate system

identification number for the grid points in the problem. However, to allow for possible exceptions, no check for this correspondence is made.) Parameter DIRECT must also be specified, defining the directions of the shock system which are to be considered. The options for DIRECT are 1, 2, 3, 12, 13, 23, and 123. For example, if DIRECT is 23, then the second and third directions of the shock coordinate system will be used. If the user does not define DIRECT, the default is 123, i.e., all three directions will be considered.

The DMAP statement for GENCOS is

```
GENCOS BGPDT, CSTM/DIRCOS/C,Y, SHOCK=0/C,Y, DIRECT=123/
      V,N, LUSET/V,N,NSCALE $
```

DDAMAT

DDAMAT calculates a matrix outer product such as that in Equation (4), and multiplies the result by parameter GG. For example, to compute effective weights, Steps 3 and 4 are performed, and $GG = g = 386.4$ if units of pounds and inches are used.

The DMAP statement for DDAMAT is

```
DDAMAT A,B/C/C,Y,GG $
```

Parameter GG must be given a value on a PARAM bulk data card or in the DMAP statement itself.

GENPART

It is assumed that, in the eigenvalue analysis, the lowest N modes were computed. If, in the static analyses (or equivalent static analyses), fewer modes are to be used, say, the lowest M , where $M < N$, then the orders of a number of matrices must be truncated. GENPART generates the partitioning vectors which NASTRAN functional module PARTN requires to partition the necessary matrices.

The DMAP statement for GENPART is

```
GENPART PF/RPLAMB,CPLAMB,RPPF,CPMP/C,Y,LNODES/V,N,MNODES $
```

Parameter LMODES is the integer value of the number of lowest modes to be used in the static analyses. The value of this parameter must be specified on a PARAM bulk data card, or else a NASTRAN fatal error will result.

DESVEL

DESVEL computes design velocity and acceleration spectra. The assumed form for velocity is

$$V = V_f V_a \frac{V_b + W}{V_c + W} \quad (6)$$

where V = velocity computed from modified effective weight W

V_f = factor usually associated with a desired direction

V_a, V_b, V_c = factors usually associated with various ship types and parameters

W = effective weight/1000.

Items V and V_a are in units of length/second, and V_b and V_c are in units of effective weight W .

Acceleration spectrum values may be expressed in one of two forms. The first form is the same as that for velocity

$$A = A_f A_a \frac{A_b + W}{A_c + W} \quad (7)$$

The second form is

$$A = A_f A_a (A_b + W) (A_c + W) / (A_d + W)^2 \quad (8)$$

where A = acceleration in g's for modified effective weight W . A_f, A_a, A_b, A_c , and A_d are factors defined similarly to factors V_f, V_a, V_b , and V_c . If $A_d = 0$, then the form of Equation (7) is used. In addition, values $V\omega/g$ are computed and are output along with acceleration values A for comparison purposes. Also, a matrix of minimum

values of $V\omega$ and A_g is output for use in Equation (5), i.e.,

$$A_{\min} = \min (V\omega, A_g) \quad (9)$$

Finally, the matrix

$$A'_{\min} = \frac{1}{\omega^2} A_{\min} \quad (9a)$$

is output for use in Equation (5f). Note that the natural frequency must not be zero. However, this is not a restriction for DDAM since a fixed base is assumed.

The DMAP statement for DESVEL is

```
DESVEL FFFW,OMEGA/SSDV,ACC,VWG,MINAG,MINOW2/C,Y,GG = 386.4/
      C,Y,VEL1/C,Y,VEL2/C,Y,VEL3/C,Y,VELA/C,Y,VELB/
      C,Y,VELC/C,Y,ACC1/C,Y,ACC2/C,Y,ACC3/C,Y,ACCA/
      C,Y,ACCB/C,Y,ACCC/C,Y,ACCD $
```

Parameter GG is the acceleration due to gravity. A default value of 386.4 is supplied. Any other value must be specified on a PARAM bulk data card. Parameters VEL1, VEL2, and VEL3 correspond to factor V_f in Equation (6) in the first, second, and third desired directions, respectively. If fewer than three directions are desired, then only VEL1, or VEL1 and VEL2, are specified. For example, if only one direction is specified, say direction 3, then VEL1 corresponds to direction 3, the first (and only) desired direction. Parameters VELA, VELB, and VELC correspond to V_a , V_b , and V_c , respectively, in Equation (6). These velocity parameters, VEL1 through VELC, must appear on PARAM bulk data cards, or else a NASTRAN fatal error will result. If VEL2 or VEL3 is not used, then values of 0. must be specified.

Acceleration parameters ACC1 through ACCD are similar to VEL1 through VELC and refer to Equations (7) and (8).

DDAMPG

DDAMPG creates the static load vectors of Equation (5) or the maximum responses of Equation (5f). For the former, the matrix $[MP] = [M][\Phi]$ is input to DDAMPG and is operated on by a matrix

$$[PVW] = [P_a] \times [A_{min}] \quad (10)$$

where $[P_a]$ is the matrix of participation factors defined by Equation (2) and $[A_{min}]$ is computed from Equation (9). The order of these matrices is $m \times l$ where m is the number of modes to be used and l is the number of desired directions. $[PVW]$ is formed by functional module DDAMAT.

The columns of $[PVW]$ correspond to desired directions. Within a column, each row term corresponds to a mode. The matrix $[MP]$ is of order $n \times m$, where n is the number of degrees-of-freedom in the problem. Each column of $[MP]$ corresponds to a mode, and in each column of $[PVW]$, the i th row term of $[PVW]$ multiplies the i th column of $[MP]$. After all columns of $[PVW]$ have been considered, the resulting static load matrix is of order $n \times (ml)$.

To compute the maximum response of Equation (5f), the same operations just described are performed, except that matrix $[PHIG] = [\Phi]$ replaces $[MP]$ and

$$[PVOW] = \frac{1}{\omega^2} [A_{min}] \quad (10a)$$

replaces $[PVW]$, where $\omega = \omega_a$ for the a th row of $[A_{min}]$.

The DMAP statement for DDAMPG for static loads is

```
DDAMPG MP,PVW/PG/V,N,NMODES/V,N,NDIR $
```

For maximum responses, the DMAP statement is

```
DDAMPG PHIG,PVOW/UCV/V,N,NMODES/V,N,NDIR $
```

CASEGEN

The static load and maximum response vectors created in DDAMPG are considered individual load cases by NASTRAN and must, therefore, be selected in the Case Control Deck. The number of cases then is $m \times l$. For example, the use of 30 modes and 3 directions gives a total of 90 cases. Rather than having the user generate the SULCASE cards, CASEGEN generates a new Case Control Data Table which includes the required cards.

The DMAP statement for CASEGEN is

```
CASEGEN CASECC/CASEDD/C,Y,LMODES/V,N,NDIR/V,N,NMODES $
```

Parameter LMODES has the same meaning here as in functional module GENPART and must appear on .PARAM bulk data card, or else a NASTRAN fatal error will result.

NRLSUM

Functional module NRLSUM computes the NRL sum stresses and forces over the m maximum responses for a given direction for each requested element. The NRL sum stress for a given stress component is

$$S = |S_{\max}| + \sqrt{\sum_{\substack{j \\ j \neq \max}} S_j^2} \quad (11)$$

where S_j is the stress component for the j th mode and $S_{\max}$ is the maximum of these stress components taken over all modes under consideration. The Case Control requests for stresses and forces are made in the usual way, except that SORT2 format must be specified. The output device for the NRL sums (printer, punch, or both) will be the same as that for the standard stresses and forces. If principal stresses are computed for an element, they will be computed on the basis of the NRL sum of the normal stresses. For the BAR element, the element axial stress in a mode will be added to each of the extensional stresses due to bending in that mode. The NRL sums will then be computed for these new extensional stresses. The NRL sums corresponding to the printed columns headed by AXIAL STRESS, SA-MAX, SB-MAX, SA-MIN, and SB-MIN will be set to 0.

In seismic analyses, the square root of the sums of the squares (SQRSS) is used rather than the NRL sums for the stresses and forces. The user may select the latter method.

The DMAP statement for NRLSUM is

```
NRLSUM OES2, OEF2/NRLSTR, NRLFOR/V, N, NMODES/V, N, NDIR/C, Y, DIRECT = 123/C, Y, SQRSS = 0 $
```

Parameter DIRECT has the same meaning here as in functional module GENCOS. Integer parameter SQRSS indicates whether the summing process should use NRL sums or the SQRSS method. A value of 0 (the default) indicates NRL sums; a value of 1, SQRSS.

COMBUGV

COMBUGV combines the direction-dependent maximum responses in a number of ways. The work being reported is intended for DDAM analyses, but seismic analyses, which make use of a similar theory, may also be run. In seismic analysis, unlike DDAM, the maximum responses in the three directions for each mode are combined into one total response for the mode. This combination may be performed by simply adding the absolute values of the maximum component responses for the mode, or by computing the square root of the sum of the squares (SQRSS) of the component responses. In both cases, the result is a matrix in which each column represents a total response due to a mode. These responses are then combined by the SQRSS method over the modes to give a final response vector. Finally, the NRL sums of the displacements are also computed.

The DMAP statement for COMBUGV is

```
COMBUGV UGV/UGVADD, UGVSQR, UGVADC, UGVSQC, UGVNRL/V, N, NMODES/V, N, NDIR $
```

Data block UGVADD is obtained by adding, for each mode, the absolute values of the component responses for that mode. Data block UGVSQR is obtained by using the SQRSS method, rather than by adding. Data blocks UGVADC and UGVSQC are obtained from UGVADD and UGVSQR, respectively, by combining the total modal responses using the SQRSS method. Data block UGVNRL contains the NRL sums of the displacements.

NASTRAN INPUT DETAILS

A complete DDAM analysis with NASTRAN is performed in one normal modes analysis run with a set of DMAP ALTERs. This section describes the input details for such a run.

EXECUTIVE CONTROL DECK

In addition to standard Executive Control Deck cards, the Executive Control Deck for the normal modes analysis must include the proper rigid format selection, SOL 3,0 and the following DMAP ALTER package (for Level 17.5). (The numbers to the left of each card are for explanatory purposes only and are not actually entered on the card.)

1. ALTER 133
2. GENCOS BGPDT, CSTM/DIRCOS/C,Y,SHOCK = 0/C,Y,DIRECT = 123/
V,N,LUSET/V,N,NSCALE \$
3. SAVE NSCALE \$
4. CHPNT DIRCOS \$
5. DIAGONAL MI/MID/C,N,SQUARE/C,N,-1. \$
6. MPYAD MGG, PHIG,/MP/C,N,0 \$
7. MPYAD MP, DIRCOS,/PMD/C,N,1 \$
8. MPYAD MID,PMD,/PF/C,N,0 \$
9. CHPNT MID, MP, PMD, PF \$
10. DDAMAT PF, PMD/EFFW/C,Y,GG = 386.4 \$
11. CHPNT EFFW \$
12. LAMX, ,LAMA/LAMB/C,N,-1 \$
13. CHPNT LAMB \$
14. GENPART PF/RPLAMB,CPLAMB,RPPF,CPMP/C,Y,LMODES/V,N,NMODES \$
15. SAVE NMODES \$
16. PARTN LAMB,CPLAMB,RPLAMB/,,,OMEGA/C,N,1 \$
17. CHPNT OMEGA \$
18. PARAM //C,N,GE/V,N,TEST/C,Y,LMODES/V,N,NMODES \$
19. COND DDAM, TEST \$
20. PARTN PF,,RPPF/,PFR,,/C,N,1 \$

21. CHKPNT PFR \$
 22. EQUIV PFR,PF \$
 23. CHKPNT PF \$
 24. PARTN EFFW,,RPPF/,EFFWR,,/C,N,1 \$
 25. CHKPNT EFFWR \$
 26. EQUIV EFFWR,EFFW \$
 27. CHKPNT EFFW \$
 28. PARTN MP,CPMP,/,,MPR,/C,N,1 \$
 29. CHKPNT MPR \$
 30. EQUIV MPR,MP \$
 31. CHKPNT MP \$
 32. PARTN PHIG,CPMP,/,,PHIGR,/C,N,1 \$
 33. CHKPNT PHIGR \$
 34. EQUIV PHIGR,PHIG \$
 35. CHKPNT PHIG \$
 36. LABEL DDAM \$
 37. DESVEL EFFW,OMEGA/SSDV,ACC,VWG,MINAC,MINOW2/C,Y,GG=386.4/C,Y,VEL1/
 C,Y,VEL2/C,Y,VEL3/C,Y,VELA/C,Y,VELB/C,Y,VELC/C,Y,ACC1/
 C,Y,ACC2/C,Y,ACC3/C,Y,ACCA/C,Y,ACCB/C,Y,ACCC/C,Y,ACCD \$
 38. CHKPNT SSDV,ACC,VWG,MINAC,MINOW2 \$
 39. DDAMAT PF,MINAC/PVW/C,N,1. \$
 40. CHKPNT PVW \$
 41. DDAMAT PF,MINOW2/PVOW/C,N,1. \$
 42. CHKPNT PVOW \$
 43. DDAMPG PHIG,PVOW/UGV/V,N,NMODES/V,N,NDIR \$
 44. SAVE NMODES,NDIR \$
 45. CHKPNT UGV \$
 46. DDAMPG MP,PVW/PG/V,N,NMODES/V,N,NDIR \$
 47. CHKPNT PG \$
 48. CASEGEN CASECC/CASEDD/C,Y,LMODES/V,N,NDIR/V,N,NMODES \$
 49. EQUIV CASEDD,CASECC \$
 50. SDR2 CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDT,,QG,UGV,EST,,/
 OQG3,OUGV3,OES3,OEF3,/C,N,STATICS/V,N,NOSORT2 = -1/C,N,-1 \$

```

51. SAVE NOSORT2 $
52. SDR3 OUGV3,,OQG3,OEF3,OES3,/OUGV4,,OQG4,OEF4,OES4, $
53. NRLSUM OES4,OEF4/NRLSTR,NRLFOR/V,N,NMODES/V,N,NDIR/C,Y,DIRECT = 123/
    C,Y,SQRSS = 0 $
54. OFF NRLSTR,NRLFOR,,,,//V,N,CARDNO $
55. SAVE CARDNO $
56. COMBUGV UGV/UGVADD,UGVSQR,UGVADC,UGVSQC,UGVNRL/V,N,NMODES/V,N,NDIR $
57. CASEGEN CASECC/CASEEE/C,N,1/V,N,NDIR/V,N,NMODES $
58. SDR2 CASEEE,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDT,,QG,UGVNRL,EST,,/,OUGV5,,,/
    C,N,STATICS/V,N,NOSORT2/C,N,-1 $
59. SAVE NOSORT2 $
60. OFF OUGV5,,,,//V,N,CARDNO $
61. SAVE CARDNO $
62. ENDALTER

```

The following notes on the functional module executions are keyed to the cards by corresponding number.

2. Computes direction cosine matrix $[V]$ in Equation (1a).
5. Creates a diagonal matrix, consisting of the diagonal of the modal mass matrix, and inverts it. The new matrix is used in Equation (2).
6. Computes $[M][\Phi]$ for later use.
7. Computes $[\Phi]^T [M] [V]$ as described in Equation (1a).
8. Computes matrix of participation factors $[P_a]$ (Equation (2)).
10. Computes effective masses and weights in Equation (4).
12. Creates a matrix of the information in the Real Eigenvalue Table for later use in Equation (5).
14. Creates partitioning vectors which will be used to create a vector of natural circular frequencies from a matrix of miscellaneous eigenvalue results. Additionally, if the number of modes to be used in computing maximum responses is less than the number computed in the normal modes analysis, other partitioning vectors are created to reduce the orders of a number of matrices.
16. Creates the vector of natural circular frequencies.
18. Compares the number of desired modes (LMODES) and the number of computed modes (NMODES).

19. If $LMODES \geq NMODES$, skips to 36.
- 20-35. Reduces orders of several matrices from $NMODES$ to $LMODES$.
37. Computes shock spectrum design velocities and accelerations, as given in Equations (6) through (8). In addition, matrices corresponding to Equations (9) and (9a) are created for use in Equations (5) and (5f), respectively. If Equations (6) through (9) do not represent the desired forms for velocities and accelerations, matrix MINAC or MINOW2 may be directly specified on DMI bulk data cards and functional module DESVEL may be deleted. MINAC and MINOW2 must be of order $LMODES \times L$; $LMODES$ is explained in 6 above, and L is the number of desired directions.
39. Creates the outer product of Equation (10).
41. Creates the matrix of Equation (10a).
43. Computes the $LMODES \times L$ matrix of direction-dependent maximum responses.
46. Creates the $LMODES \times L$ static load matrix as in Equation (5).
48. Generates a new Case Control Data Table which includes the $(LMODES \times L)$ subcases.
50. Computes stresses due to each maximum response.
52. Converts stresses in 50. from SORT1 to SORT2.
53. Computes the NRL sum or SQRSS stresses and forces for each requested element.
54. Outputs the NRL sum stresses and forces to the printer and/or punch, as requested in the Case Control Deck.
56. Computes various combinations of the component maximum responses.
- 57-61. Prepares and prints file of NRL sum displacements.

CASE CONTROL DECK

Although the usual selections may be made, two requirements are imposed:

1. No subcases are to be specified.
2. Stress and force selections must request SORT2 format.

This last requirement will force all output selections, e.g., displacements, applied loads, etc., to be in SORT2 format. Also, the NRL sum stresses and forces will be printed and/or punched, as requested in the corresponding STRESS and FORCE requests.

BULK DATA DECK

The values of a number of parameters special to DDAM must be specified. For those parameters with no default values and for parameters for which the default values are to be overridden, PARAM bulk data cards will be required. The parameters are as follows:

1. SHOCK - The nonnegative integer value of this parameter is the identification number of the coordinate system which defines the shock directions. A non-zero value requires definition of the system on a CORDij card. A zero value implies the basic coordinate system with shock directions X, Y, and Z. The default value is zero. The value of SHOCK should, in most cases, be the same as the displacement coordinate system identification number for the grid points.

2. DIRECT - This parameter may have one of the following integer values: 1, 2, 3, 12, 13, 23, or 123. The default value is 123. The value of DIRECT indicates which directions of coordinate system SHOCK are to be considered. For example, if DIRECT = 123, then all three directions will be used. If DIRECT = 13, only two directions will be used, the first and the third.

3. GG - This parameter is the acceleration due to gravity. The default value is 386.4.

4. LMODES - The integer value of this parameter is the number of lowest modes to be used in the static analyses. This number may be less than the number of modes computed in the normal modes analysis. No default value is provided so the value of this parameter must be given on a PARAM bulk data card or else a fatal message will result.

5. VEL1,VEL2,VEL3,VELA,VELB,VELC,ACC1,ACC2,ACC3,ACCA,ACCB,ACCC,ACCD -
The real values of these parameters control the computation of the shock spectrum design values for velocity and acceleration. These parameters are defined by Equations (6) through (8) and further explained on pages 7 and 8. No default values for any of these parameters are provided, so a PARAM bulk data card for each parameter must be included in the Bulk Data Deck.

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