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FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES IN NASTRAN

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by

V. Elchuri

A. Michael Gallo

S. C. Skalski

Bell Aerospace Textron
P. O. Box One
Buffalo, New York 14240

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16. Abstract

A new capability has been added to the general purpose finite element program NASTRAN Level 17.7 to conduct forced vibration analysis of tuned cyclic structures rotating about their axis of symmetry. The effects of Coriolis and centripetal accelerations together with those due to linear acceleration of the axis of rotation have been included.

This report presents the Theoretical, User's, Programmer's and Demonstration manuals for this new capability. The work was conducted under Contract NAS3-22533 from NASA Lewis Research Center, Cleveland, Ohio, with Mr. Richard E. Morris as the Technical Monitor.

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A new capability has been added to the general purpose finite element program NASTRAN Level 17.7 to conduct forced vibration analysis of tuned cyclic structures rotating about their axis of symmetry. The effects of Coriolis and centripetal accelerations together with those due to linear acceleration of the axis of rotation have been included.

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I. THEORETICAL MANUAL

FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES

1.1 Introduction

A new capability has been developed and implemented in NASTRAN Level 17.7 to perform forced vibration analysis of cyclic structures rotating about their axis of symmetry. Fans, propellers, and bladed shrouded discs of turbomachines are some examples of such structures. The capability includes the effects of Coriolis and centripetal accelerations on the rotating structure which can be loaded with:

1) directly applied loads moving with the structure and
2) inertial loads due to the translational acceleration of the axis of rotation ('base' acceleration).

One rotationally cyclic sector of the N-sectored structure is modelled and analyzed. Steady-state sinusoidal or general periodic loads are specified to represent:

1) the physical loads on various segments of the complete structure, or
2) the circumferential harmonic components of the loads in (1).

The sinusoidal loads are specified as functions of frequency and the general periodic loads are specified as functions of time.

The translational acceleration of the axis of rotation may be specified as a function of frequency in an inertial coordinate system.

The details of the User's, Programmer's and Demonstration manuals are presented in Sections 2, 3 and 4, respectively. The following sections present the salient points in the theoretical development.

1.2 Theory

The theoretical development of Reference 1 to conduct forced vibration analysis of rotating cyclic structures in conjunction with the theory of rotational cyclic symmetry as presented in Section 4.5.1 of the NASTRAN Theoretical Manual (Reference 2) is summarized in this section.

1.2.1 Equations of Motion

The complete structure consists of N identical sectors. The displacement at any grid point in any sector can be expressed in any body-fixed coordinate system as a combination of:

1) the steady displacement due to the steady rotation of the structure, and
2) the vibratory displacement (superposed on the steady displacement) due to the vibratory excitation provided by the directly applied loads and base acceleration.

The vibratory response of rotating cyclic structures may be determined by this new capability.

As shown in Reference 1, the equations of forced response can be written as

$$M^n\ddot{u}^n + B^n\dot{u}^n + K^n u^n = P^n - M_2^n\ddot{R} \quad , n = 1, 2, \ldots, N. \qquad (1)$$

For the n^{th} cyclic sector, u^n represents the vibratory degrees of freedom; M^n, B^n and K^n represent its mass, damping and stiffness matrices respectively; P^n represents the directly applied loads on u^n, and $-M_2^n\ddot{R}$ represents the inertial loads on u^n due to base acceleration $\ddot{R}$. The damping matrix B^n consists of the viscous and structural damping, and the contribution due to the Coriolis acceleration, i.e.,

$$B^n = B^n_{\substack{\text{viscous,}\\\text{structural}}} + 2\Omega B^n_{\text{Coriolis}}, \qquad (2)$$

with Ω as the (constant) rotational speed. The stiffness matrix K^n consists of elastic and differential stiffness together with the contribution due to the centripetal acceleration, i.e.,

$$K^n = K^n_{\text{elastic}} + K^n_{\text{differential}} - \Omega^2 M^n_{\text{centripetal}} . \qquad (3)$$

The derivation of the coefficient matrices B^n_{Coriolis}, $M^n_{\text{centripetal}}$ and M_2^n is given in Reference 1.

Equations (1) supplemented by the inter-segment boundary compatibility conditions (Section 4.5.1, Reference 2),

$$u^{n+1}_{\text{side 1}} = u^n_{\text{side 2}}, \; n = 1, 2, \ldots, N, \qquad (4)$$

completely describe the vibratory forced motion of the rotating cyclic structure.

1.2.2 Method of Solution

The method of solution of equations (1) consists of four principal steps:

1) Transformation of applied loads to frequency-dependent circumferential harmonic components.

2) Application of circumferential harmonic-dependent inter-segment compatibility constraints.

3) Solution of frequency-dependent circumferential harmonic components of displacements.

4) Recovery of frequency-dependent response (displacements, stresses, loads, etc.) in various segments of the total structure.

An overall flowchart outlining the solution algorithm is shown in Figure 1.

1. Transformation of Applied Loads

The transformation to frequency-dependent circumferential harmonic components depends on the form in which the excitation is specified by the user. The following options are made available in the present capability to specify the form of excitation due to the directly applied loads and base acceleration loads:

Directly applied loads specified as:

- periodic functions of time on various segments
- periodic functions of time for various circumferential harmonic indices
- functions of frequency on various segments
- functions of frequency for various circumferential harmonic indices.

Base acceleration specified as:

- function of frequency for circumferential harmonic indices 0 (axial) and 1 (lateral).

Details of each of the above five loading conditions are as follows.

Directly applied loads (segment-dependent and periodic in time)

If P^n represents a general periodic load on sector n specified as a function of time at M equally spaced instances of time per period (Figure 2), the load at m^{th} time instant can be written as

$$\overset{m}{P^n} = \overset{-o}{P^n} + \sum_{\ell=1}^{\ell_L}\left[\overset{-\ell c}{P^n}\cos(\overline{m-1}\;\ell b) + \overset{-\ell s}{P^n}\sin(\overline{m-1}\,\ell b)\right] + (-1)^{m-1}\overset{-M/2}{P^n}\quad , \qquad (5)$$

$$m = 1, 2, \ldots, M \quad ,$$

where $b = 2\pi/M$, $\ell_L = (M-1)/2$ for odd M, $\ell_L = (M-2)/2$ for even M. The last term in equation (5) exists only when M is even. The coefficients $\overset{-"\ell"}{P^n}$ ($"\ell" = 0;\ \ell c,\ \ell s,\ \ell=1, 2, \ldots, \ell_L;\ M/2$) in equation (5) are independent of time, and are defined by the relations

$$\overset{-o}{P^n} = \frac{1}{M}\sum_{m=1}^{M}\overset{m}{P^n} \quad , \qquad (\ell = 0) \qquad \text{part of (6)}$$

$$\left.\begin{array}{l}
\left.\begin{array}{l}
\overset{-\ell c}{P^{n}} = \frac{2}{M}\sum_{m=1}^{M} \overset{m}{P^{n}} \cos(\overline{m-1}\ell b), \\[2ex]
\overset{-\ell s}{P^{n}} = \frac{2}{M}\sum_{m=1}^{M} \overset{m}{P^{n}} \sin(\overline{m-1}\ell b), \quad \text{and}
\end{array}\right\} (\ell = 1,\ 2,\ \ldots,\ \ell_L) \\[4ex]
\overset{-M/2}{P^{n}} = \frac{1}{M}\sum_{m=1}^{M} (-1)^{m-1}\, \overset{m}{P^{n}} \ (M\text{ even only}) \quad (\ell = M/2).
\end{array}\right\} \text{(6 Contd.)}$$

Each of the coefficient vectors $\overset{-"\ell"}{P^{n}}$ on the left hand sides of equations (6) can further be expanded in a circumferential (truncated) Fourier series

$$\overset{-"\ell"}{P^{n}} = \overset{-"\ell"}{\bar{P}^{0}} + \sum_{k=1}^{k_L}\left[\overset{-"\ell"}{\bar{P}^{kc}} \cos(\overline{n-1}ka) + \overset{-"\ell"}{\bar{P}^{ks}} \sin(\overline{n-1}ka)\right] + (-1)^{n-1}\overset{-"\ell"}{\bar{P}^{N/2}} \ , \tag{7}$$

$$\left.\begin{array}{l}
\text{where } n = 1,\ 2,\ \ldots,\ N \ , \\
"\ell" = 0;\ \ell c,\ \ell s,\ \ell = 1,\ 2,\ \ldots,\ \ell_L;\ M/2 \\
a \ = 2\pi/N \\
k_L = (N-1)/2 \text{ for } N \text{ odd} \\
k_L = (N-2)/2 \text{ for } N \text{ even.}
\end{array}\right\} \quad (8)$$

The last term in equation (7) exists only when N is even. The Fourier coefficients $\overset{-"\ell"}{\bar{P}^{"k"}}$ ("k" = 0; kc, ks, k = 1, 2, ..., k_L; N/2) in equation (7) do not vary from sector to sector, and are defined by

$$\left.\begin{array}{l}
\overset{-"\ell"}{\bar{P}^{0}} = \frac{1}{N}\sum_{n=1}^{N} \overset{-"\ell"}{P^{n}} \qquad\qquad (k = 0) \\[3ex]
\left.\begin{array}{l}
\overset{-"\ell"}{\bar{P}^{kc}} = \frac{2}{N}\sum_{n=1}^{N} \overset{-"\ell"}{P^{n}} \cos(\overline{n-1}ka) \\[3ex]
\overset{-"\ell"}{\bar{P}^{ks}} = \frac{2}{N}\sum_{n=1}^{N} \overset{-"\ell"}{P^{n}} \sin(\overline{n-1}ka), \text{ and}
\end{array}\right\} (k = 1,\ 2,\ \ldots,\ k_L) \\[3ex]
\overset{-"\ell"}{\bar{P}^{N/2}} = \frac{1}{N}\sum_{n=1}^{N} (-1)^{n-1}\, \overset{"\ell"}{P^{n}} \quad (N\text{ even only}) \quad (k = N/2) \ .
\end{array}\right\} \quad (9)$$

The terms $\bar{P}^{-"\ell"}_{"k"}$ ("ℓ" = 0; ℓc, ℓs, ℓ = 1, 2, ..., ℓ_L; M/2 and "k" = 0; kc, ks, k = 1, 2, ..., k_L; N/2) are the <u>transformed</u> frequency-dependent circumferential harmonic components of the directly applied loads P^m_n (m = 1, 2, ..., M and n = 1, 2, ..., N).

<u>Directly applied loads (Circumferential harmonic-dependent and periodic in time)</u>.

Such loads can be represented as

$$\bar{P}^{m}_{"k"} = \bar{P}^{-0}_{"k"} + \sum_{\ell=1}^{\ell_L} \left[\bar{P}^{-\ell c}_{"k"} \cos(\overline{m-1}\ell b) + \bar{P}^{-\ell s}_{"k"} \sin(\overline{m-1}\ell b) \right] + (-1)^{m-1} \bar{P}^{-M/2}_{"k"} , \quad (10)$$

where m = 1, 2, ..., M represent the time instances at which harmonic components "k" = 0; kc, ks, k = 1, 2, ..., k_L; N/2 of directly applied loads are specified.

The coefficients $\bar{P}^{-"\ell"}_{"k"}$ on the right hand side of equation (10) are obtained using equations (6) with sector number n replaced by harmonic number "k".

<u>Directly applied loads (frequency-and segment-dependent)</u>

This type of loads can be represented as

$$P^{-"\ell"}_{n} = \bar{P}^{-"\ell"}_{0} + \sum_{k=1}^{k_L} \left[\bar{P}^{-"\ell"}_{kc} \cos(\overline{n-1}ka) + \bar{P}^{-"\ell"}_{ks} \sin(\overline{n-1}ka) \right] + (-1)^{n-1} \bar{P}^{-"\ell"}_{N/2} , \quad (11)$$

where "ℓ" (=1, 2, ..., F) now represents the frequencies at which excitation is specified. The transformed frequency-dependent circumferential harmonic components $\bar{P}^{-"\ell"}_{"k"}$ ("k" = 0; kc, ks, k = 1, 2, ..., k_L; N/2) are obtained using equations (9) with "ℓ" as defined above.

<u>Directly applied loads (frequency-and circumferential harmonic-dependent)</u>

These loads <u>are</u> the transformed frequency-dependent circumferential harmonic components $\bar{P}^{-"\ell"}_{"k"}$ ("k" = 0; kc, ks, k = 1, 2, ..., k_L; N/2) with "ℓ" (=1, 2, ..., F) representing the various frequencies at which the directl, applied loads are specified.

<u>Base acceleration (frequency- and circumferential harmonic-dependent)</u>

In Reference 1, it is shown that the components of the translational base acceleration contribute to inertial loads on the rotating structure in the following manner:

1. Axial component contributes to $\bar{P}^{"k"}_{"\ell"}$ where "k" = 0, and "ℓ" represents the specified excitation frequencies.

2. Lateral components contribute to $\bar{P}^{"k"}_{"\ell"}$ where "k" = 1c and 1s, and "ℓ" represents the effective excitation frequencies which are shifted from the specified frequencies by $\pm\,\Omega$, the rotational frequency.

The user specifies the components of the base acceleration vector $\ddot{R}$ as functions of frequency. The program computes the inertial loads $-M_2^n\ddot{R}$ and transforms them to appropriate frequency-dependent circumferential harmonic components.

2. Application of Inter-Segment Compatibility Constraints

As shown in Section 4.5.1 of Reference 2, equations (4) are used to derive the compatibility conditions relating the circumferential harmonic component degrees of freedom on the two sides of a rotationally cyclic sector:

$$\left.\begin{aligned}
&\underline{\text{side 2}} && \underline{\text{side 1}} && \\
&\bar{u}_2^o &=\;& \bar{u}_1^o && (k = o)\\
&\bar{u}_2^{kc} &=\;& \bar{u}_1^{kc}\cos(ka) + \bar{u}_1^{ks}\sin(ka) && \\
&\bar{u}_2^{ks} &=\;& -\bar{u}_1^{kc}\sin(ka) + \bar{u}_1^{ks}\cos(ka) && (k = 1, 2, \ldots, k_L)\\
\text{and}\quad &\bar{u}_2^{N/2} &=\;& -\bar{u}_1^{N/2}\;. && (k = N/2)
\end{aligned}\right\} \qquad (12)$$

In order to apply these constraint relationships for any given harmonic k, an independent set $\bar{u}^K$ consisting of the circumferential harmonic component (cosine and sine) degrees of freedom from the interior and side 1 of the cyclic sector is defined. $\bar{u}^K$ is selected from the 'analysis' set degrees of freedom, and is defined as

$$\left.\begin{aligned}
\bar{u}^{kc} &= G_{ck}(k)\,\bar{u}^K, \quad \text{and}\\
\bar{u}^{ks} &= G_{sk}(k)\,\bar{u}^K\;.
\end{aligned}\right\} \qquad (13)$$

$\bar{u}^{kc}$ and $\bar{u}^{ks}$ each contain all (and only) the 'analysis' set degrees of freedom from the interior and both sides of the cyclic sector. Equations (12) are used to define some of the elements of the transformation matrices G_{ck} and G_{sk}. For k = o and N/2, the matrix G_{sk} is null.

3. Solution of Frequency-Dependent Harmonic Displacements

For a given harmonic k, the introduction of $\bar{u}^K$ in the equations of motion, (1), results in the transformed equations of motion (Reference 3)

$$\bar{M}^K\ddot{\bar{u}}^K + \bar{B}^K\dot{\bar{u}}^K + \bar{K}^K\bar{u}^K = \bar{P}^K \quad , \tag{14}$$

where

$$\left.\begin{aligned} \bar{M}^K &= G_{ck}^T M^n G_{ck} + G_{sk}^T M^n G_{sk} , \\ \bar{B}^K &= G_{ck}^T B^n G_{ck} + G_{sk}^T B^n G_{sk} , \\ \bar{K}^K &= G_{ck}^T K^n G_{ck} + G_{sk}^T K^n G_{sk} , \text{ and} \\ \bar{P}^K &= G_{ck}^T \bar{P}^{kc} + G_{sk}^T \bar{P}^{ks} \quad . \end{aligned}\right\} \tag{15}$$

As discussed in subsection 1 of Section 1.2.2, $\bar{P}^{kc}$ and $\bar{P}^{ks}$ are the transformed frequency-dependent circumferential harmonic components of the directly applied and base acceleration loads.

At any excitation frequency ω', let

$$\left.\begin{aligned} \bar{P}^K &= \bar{\bar{P}}^K e^{i\omega' t} \quad \text{and accordingly,} \\ \bar{u}^K &= \bar{\bar{u}}^K e^{i\omega' t} \quad , \end{aligned}\right\} \tag{16}$$

where $\bar{\bar{P}}^K$ and $\bar{\bar{u}}^K$ are complex quantities. Equation (14) can be rewritten as

$$[-\omega'^2 \bar{M}^K + i\omega' \bar{B}^K + \bar{K}^K]\bar{\bar{u}}^K = \bar{\bar{P}}^K \quad . \tag{17}$$

The excitation frequency ω' is given by

$$\left.\begin{aligned} \omega' &= \omega \text{ for all directly applied and axial base acceleration loads, and} \\ &= \omega \pm \Omega \text{ for lateral base acceleration loads.} \end{aligned}\right\} \tag{18}$$

Equation (17) is solved for $\bar{\bar{u}}^K$ for all excitation frequencies and all harmonics as specified by the user. The cosine and sine harmonic components of displacements are recovered using equations (13).

4. Recovery of Frequency-Dependent Displacements in Various Segments

This step is carried out only when the applied loads are specified on the various segments of the complete structure.

For loads specified as functions of time, equation (7) is used to obtain the displacements $\bar{u}_n^{"\ell"}$ in various segments with "ℓ" = 0; ℓc, ℓs, $\ell = 1, 2, \ldots, \ell_{max}$. The circumferential harmonic k is varied from k_{min} to k_{max}. The user specifies ℓ_{max}, k_{min} and k_{max}.

For loads specified as functions of frequency, equation (11) is used to obtain the displacements $\bar{u}_n^{"\ell"}$ in various segments with "ℓ" representing the excitation frequencies. The circumferential harmonic is varied from user specified k_{min} to k_{max}.

The recovery of other responses such as stresses, internal forces, etc., is identical to that currently existent in NASTRAN.

1.3 References

1. Elchuri, V., Smith, G. C. C., "Finite Element Forced Vibration Analysis of Rotating Cyclic Structures," Final Technical Report, NASA CR-165430, December 1981.
2. The NASTRAN Theoretical Manual, Level 17.6, NASA SP-222(05), October 1980.
3. Smith, G. C. C., Elchuri, V., "Aeroelastic and Dynamic Finite Element Analyses of a Bladed Shrouded Disk," Final Technical Report, NASA CR-159728, March 1980.

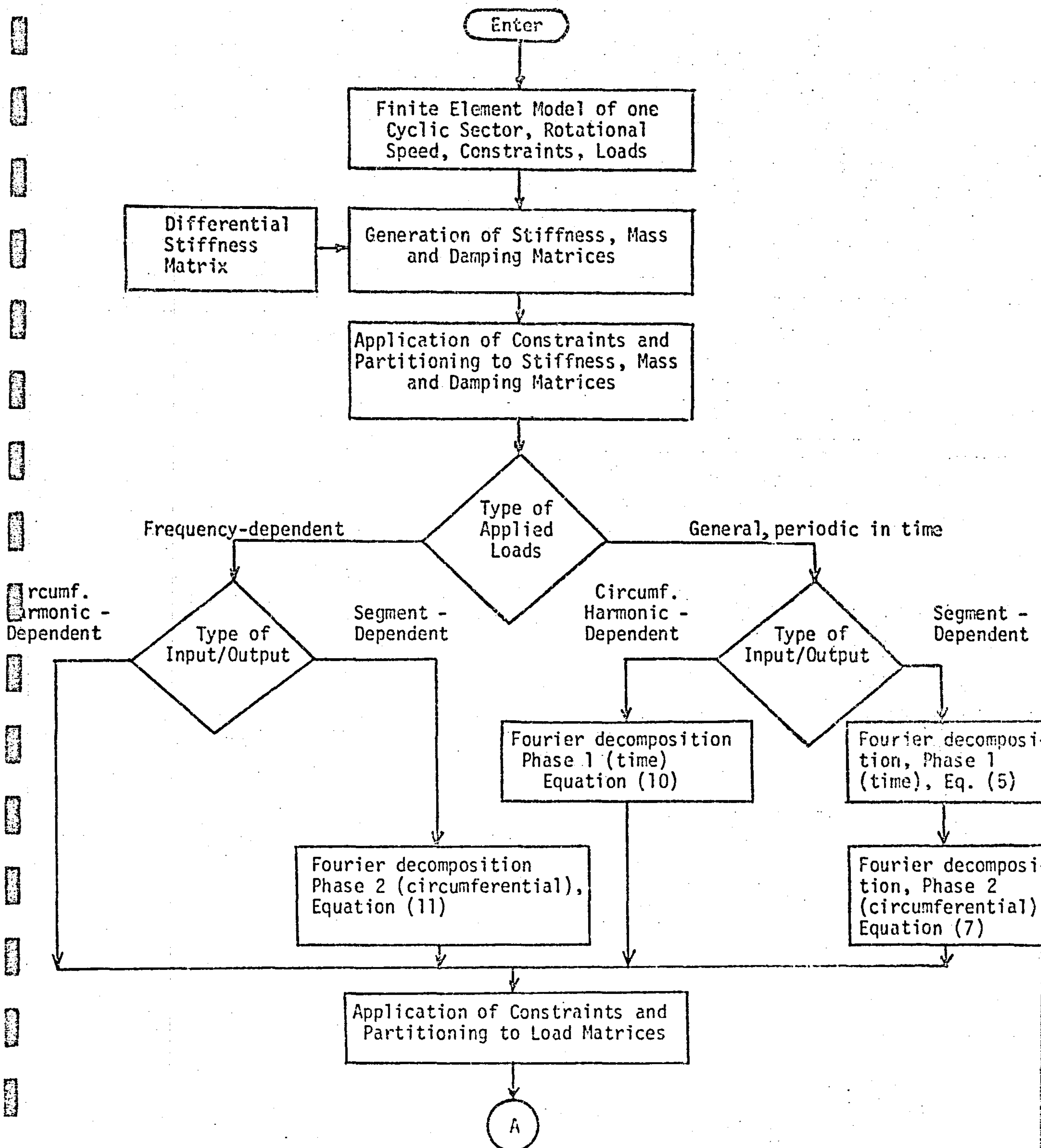

FIGURE 1: Overall Flowchart of Forced Vibration Analysis of Rotating Cyclic Structures

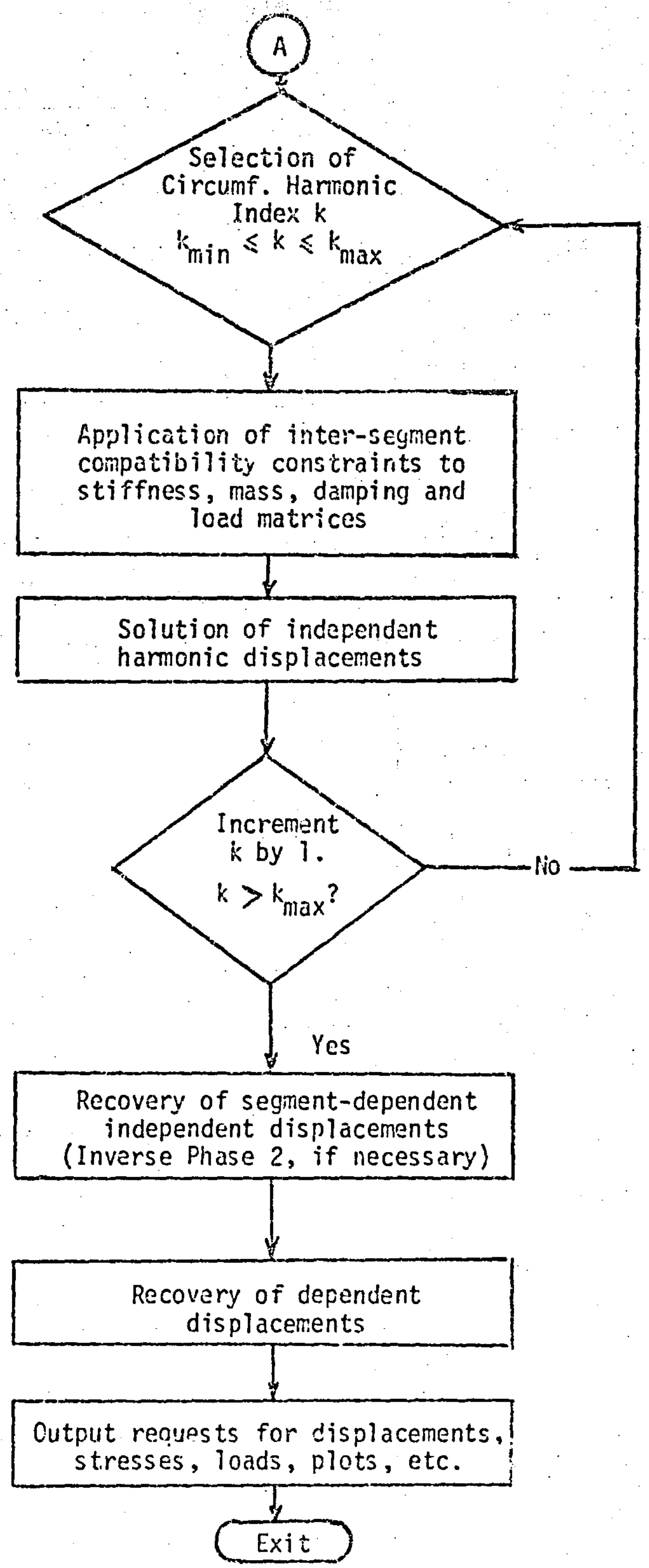

FIGURE 1. (Concluded)

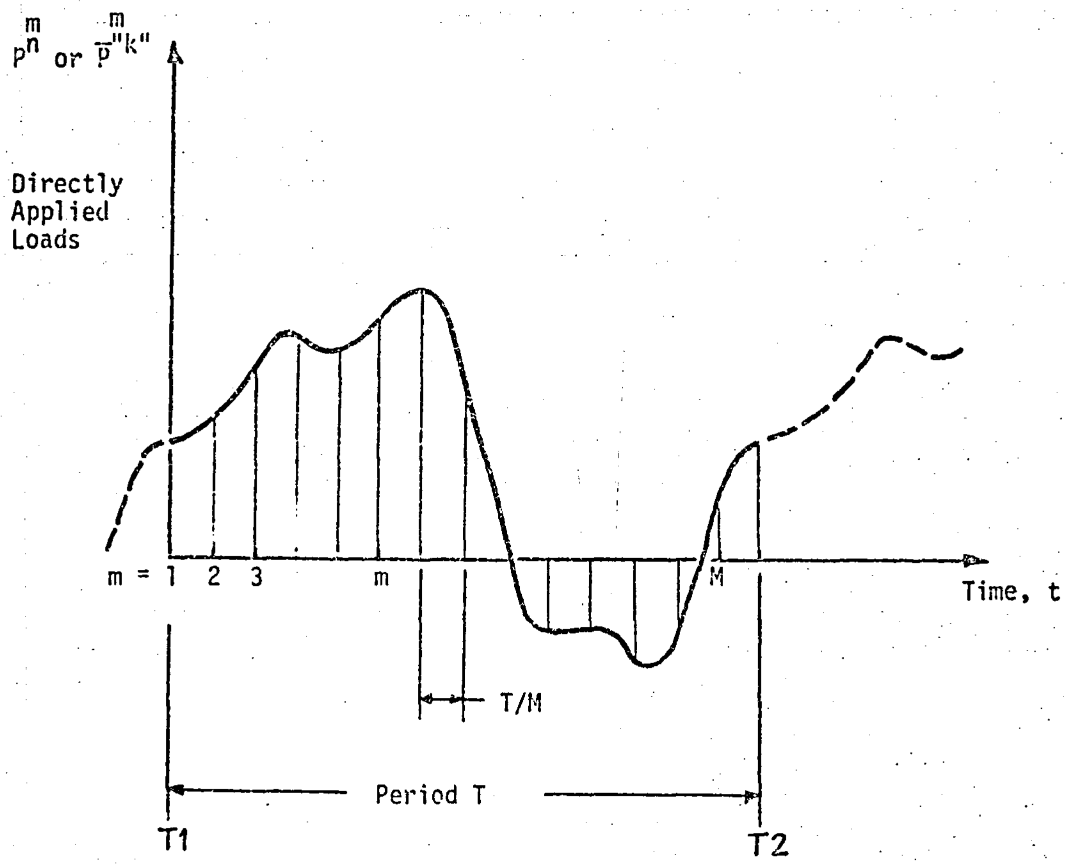

Figure 2: Directly Applied Periodic Loads Specified as Functions of Time

2. USER'S MANUAL

FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES

2.1 Introduction

Forced vibration analysis of cyclic structures rotating about their axis of symmetry can be conducted using this capability. An extensive package of ALTERs including new Functional Modules and PARAMeters has been developed and used to modify the existing Displacement Approach Rigid Format 8 (Direct Frequency and Random Response), Series R, in NASTRAN Level 17.7. Example 2 of the Demonstration Manual (Section 4) illustrates the use of this ALTER package. The Theoretical and Programmer's Manuals are described in Sections 1 and 3, respectively.

2.2 NASTRAN Model

The user models one rotationally cyclic sector (segment) of the entire structure as shown by the 12-bladed disc example in Figure 1. All NASTRAN coordinate systems (basic, location and displacement) are considered fixed to the rotating structure. The only additional requirement is that the X-axis of the basic coordinate system be coincident with the axis of rotation. A positive value of the rotational speed (PARAM RPS) indicates a clockwise sense of rotation when the structure is viewed at in the positive basic X direction.

Except for the special features discussed in this section, the general rules of modelling rotationally cyclic structures in NASTRAN (e.g. CYJOIN, NSEGS, etc.) have been maintained.

The rotating structure can be loaded with steady-state sinusoidal or general periodic loads classified as :

1. directly applied loads moving with the structure, and
2. inertial loads due to the translational acceleration of the axis of rotation ('base' acceleration).

The sinusoidal loads are specified as functions of frequency using the RLOADi bulk data cards. The general periodic loads are specified as functions of time using the TLOADi bulk data cards.

The following notes apply when using TLOADi bulk data cards:

1. Time delay τ must be set to zero.
2. In conjunction with the TSTEP bulk data card, TLOADi information is used to discretely define P(t) at M time instances as P^{m} or P'^{m}_{k} (m = 1, 2, ..., M), as discussed in Section 1.2.2 of the Theoretical

Manual.

N(1) of TSTEP bulk data card = M-2
DT(1) of TSTEP bulk data card = (T2 - T1)/M

3. P(t) is defined in the interval [T1, T2] with (T2 - T1) as the period.

4. Only one physical TSTEP bulk data card is allowed, i.e. continuation of the TSTEP card is not permitted.

The following options are provided to specify the form of excitation:

Directly applied loads specified as:

- periodic functions of time on various segments (PARAM CYCIO = +1)
- periodic functions of time for various circumferential harmonic indices (PARAM CYCIO = -1)
- functions of frequency on various segments (PARAM CYCIO = +1)
- functions of frequency for various circumferential harmonic indices (PARAM CYCIO = -1)

Base acceleration specified as:

- function of frequency for circumferential harmonic indices 0 (axial) and 1 (lateral) (PARAM CYCIO = -1)

The base acceleration refers to the translational acceleration of the axis of rotation, and is specified in an inertial coordinate system. The user defines a rectangular inertial coordinate system with its X-axis parallel to and in the direction of the basic X axis, as shown in Figure 1. The definition of this inertial system, otherwise, is arbitrary. The user specifies the X, Y, Z components (magnitude and phase) of the base acceleration vector as functions of frequency on TABLEDi bulk data cards. The use of these tables is activated by the PARAMs BXTID, BXPTID, BYTID, BYPTID, BZTID and BZPTID.

The user is provided with two options to include damping by specifying the form of the matrices K_{dd}, B_{dd} and M_{dd} in the Functional module GKAD as per equations 16 through 21, pages 9.3-7 and 9.3-8, Section 9.3.3 of the NASTRAN Level 17.7 Theoretical Manual. The PARAMeters GKAD and LGKAD have been defined for this purpose.

Section 2.4.4 of this manual describes all the PARAMeters applicable with this new capability.

2.3 Subcase Definitions

The PARAMeters CYCIO (=±1) and KMAX (≥0,≤NSEGS/2 for even NSEGS, ≤(NSEGS-1)/2 for odd NSEGS) determine the number, order and meaning of subcases as follows:

CYCIO=+1

The number of subcases is equal to NSEGS, independent of KMAX.

SUBCASE 1 (SEGMENT NO. 1)
SUBCASE 2 (SEGMENT NO. 2)
.
.
.
SUBCASE NSEGS (SEGMENT NO. NSEGS)

CYCIO=-1

The number of subcases is equal to FKMAX, where

FKMAX = 1, if KMAX = 0,
= 1 + 2 • KMAX, if 0<KMAX≤(NSEGS-1)/2, NSEGS odd,
= 1 + 2 • KMAX, if 0<KMAX≤(NSEGS-2)/2 NSEGS even, and
= NSEGS, if KMAX = NSEGS/2, NSEGS even.

SUBCASE 1 ('k' = 0)
SUBCASE 2 ('k' = 1c)
SUBCASE 3 ('k' = 1s)
SUBCASE 4 ('k' = 2c)
SUBCASE 5 ('k' = 2s)
.
.
.
SUBCASE FKMAX ('k' = KMAXs)

In the event that NSEGS is even and KMAX = NSEGS/2, Subcase FKMAX will represent 'k' = KMAXc as KMAXs does not exist.

Directly applied loads on various segments (CYCIO=+1) or their circumferential harmonic components (CYCIO=-1) are specified under the appropriate subcases. With RLOADi bulk data cards, null loads need not be specified by the user. With TLOADi bulk data cards, the user is required to provide information to generate null loads where applicable.

Base acceleration is included only when CYCIO=-1. Based on the activating PARAMeters BXTID etc., the corresponding inertial loads are internally calculated and assigned to 'k' = 0, lc and ls as applicable.

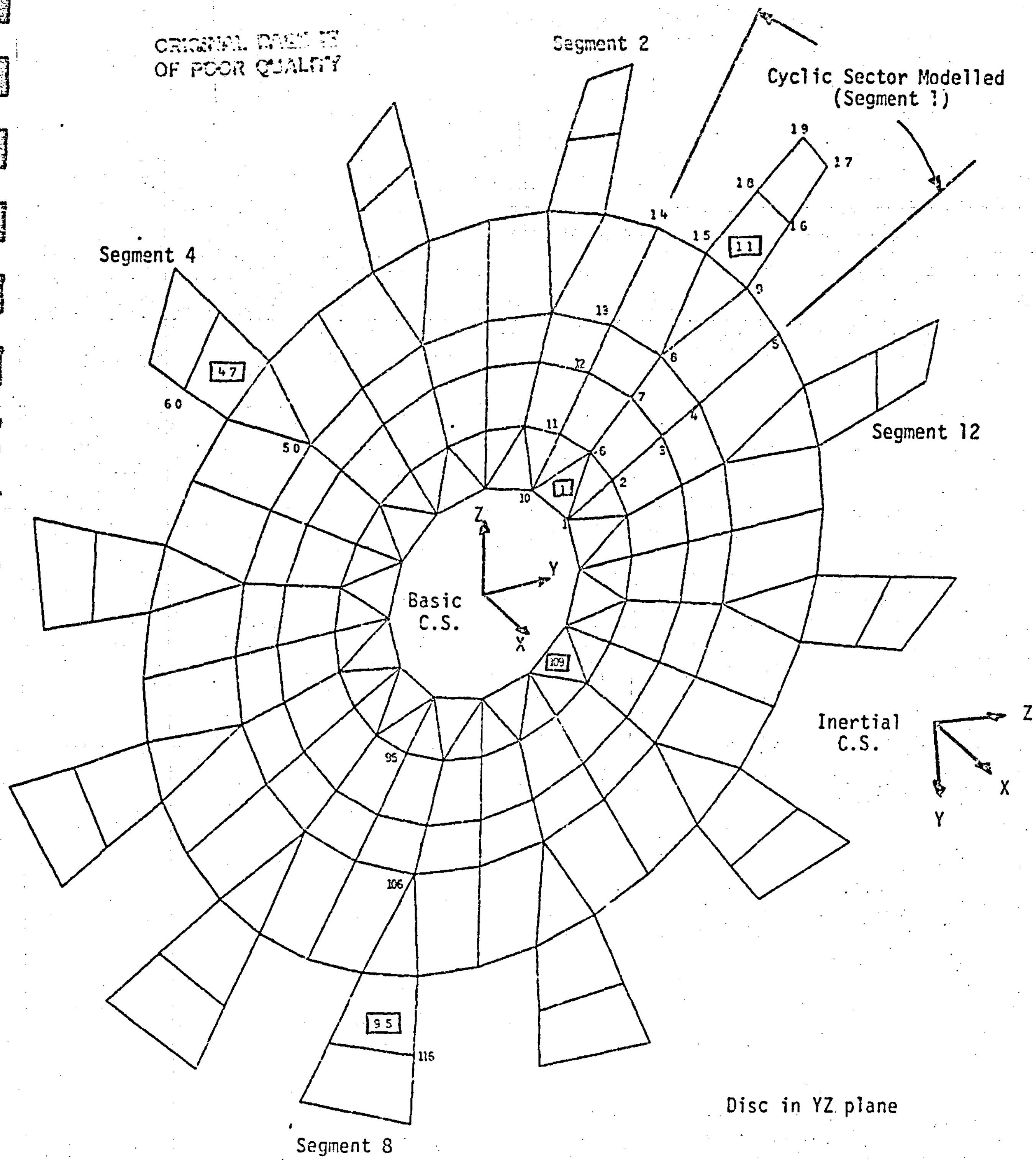

Figure 1: NASTRAN Model of the 12-Bladed Disc

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2.4 Rigid Format Description

2.4.1 Rigid Format Alters to Displacement SOL 8

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$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$                                                                      $
$ BEGINNING OF RF ALTER 8$1 - RF 8 / SERIES R (L17.7) / 1-28-82 / M.G. $
$                                                                      $
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$                                                                      $
$ PURPOSE - TO MODIFY THE DIRECT FREQUENCY AND RANDOM RESPONSE RIGID   $
$           FORMAT TO ENABLE THE USER TO PERFORM A FORCED VIBRATION    $
$           RESPONSE ANALYSIS OF ROTATING CYCLIC STRUCTURES.           $
$                                                                      $
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$ EXECUTIVE DECK INPUT -
$
$     1. SOL 8
$     2. R.F. ALTERS
$
$ CASE CONTROL DECK INPUT -
$
$     1. ALL SPC AND MPC CONSTRAINTS MUST BE ABOVE THE SUBCASE LEVEL.
$     2. EITHER FREQUENCY OR TSTEP MUST BE SELECTED AND MUST BE ABOVE
$        THE SUBCASE LEVEL.
$     3. IF SELECTED, FREQUENCY MUST BE USED TO SELECT ONE AND ONLY
$        ONE FREQ, FREQ1 OR FREQ2 CARD FROM THE BULK DATA DECK AND
$        MUST BE DEFINED ABOVE THE SUBCASE LEVEL.
$     4. IF SELECTED, TSTEP MUST BE USED TO SELECT THE TIME-STEPS TO BE
$        USED FOR LOAD DEFINITION AND MUST BE DEFINED ABOVE THE SUBCASE
$        LEVEL.
$     5. DIRECT INPUT MATRICES ARE NOT ALLOWED.
$     6. OFREQUENCY MUST NOT BE USED.
$     7. A SEPARATE GROUP OF SUBCASES MUST BE DEFINED FOR EACH SYMMETRIC
$        SEGMENT.
$     8. DLOAD MUST BE USED TO DEFINE A FREQUENCY OR TIME-DEPENDENT
$        LOADING CONDITION FOR EACH SUBCASE.
$        FOR FREQUENCY-DEPENDENT LOADS, SUBCASES WITHOUT LOADS NEED NOT
$        REFER TO A DLOAD CARD.
$        FOR TIME-DEPENDENT LOADS, SUBCASES WITHOUT LOADS MUST REFER TO
$        A DLOAD CARD THAT GENERATES A NULL LOAD.
$     9. AN ALTERNATE LOADING METHOD IS TO DEFINE A SEPARATE GROUP OF
$        SUBCASES FOR EACH HARMONIC INDEX, K. THE PARAMETER CYCIO IS
$        INCLUDED AND THE LOAD COMPONENTS FOR EACH INDEX ARE DEFINED
$        DIRECTLY WITHIN EACH GROUP FOR THE VARIOUS LOADING CONDITIONS.
$
$ BULK DATA DECK INPUT -
$
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$     1. SUPORT BULK DATA CARDS ARE NOT ALLOWED.
$     2. EPOINT BULK DATA CARDS ARE NOT ALLOWED.
$     3. SPOINT BULK DATA CARDS ARE NOT ALLOWED.
$     4. CYJOIN BULK DATA CARDS ARE REQUIRED.
$     5. IF A TSTEP CARD IS USED THEN IT MUST NOT BE CONTINUED SINCE
$        ONLY ONE UNIFORM TIME STEP INTERVAL MUST BE SPECIFIED.
$        THE SKIP FACTOR FOR OUTPUT, NO, ON THE TSTEP CARD MUST BE 1.
$     6. PARAMETERS USED ARE -
$
$        A. NSEGS     - REQUIRED - THE INTEGER VALUE OF THIS PARAMETER
$                       IS THE NUMBER OF IDENTICAL SEGMENTS IN THE
$                       STRUCTURAL MODEL.
$        B. CYCIO     - REQUIRED - THE INTEGER VALUE OF THIS PARAMETER
$                       SPECIFIES THE FORM OF THE INPUT AND OUTPUT DATA.
$                       A VALUE OF &1 IS USED TO SPECIFY PHYSICAL SEGMENT
$                       REPRESENTATION. A VALUE OF -1 IS USED TO SPECIFY
$                       CYCLIC TRANSFORMATION REPRESENTATION. THERE IS NO
$                       DEFAULT, A VALUE MUST BE INPUT.
$        C. CYCSEQ    - FIXED    - THE INTEGER VALUE OF THIS PARAMETER
$                       SPECIFIES THE PROCEDURE FOR SEQUENCING THE
$                       EQUATIONS IN THE SOLUTION SET. THE VALUE OF THIS
$                       PARAMETER HAS BEEN SET TO -1 TO SPECIFY
$                       ALTERNATING COSINE AND SINE TERMS.
$        D. CTYPE     - FIXED     - THE BCD VALUE OF THIS PARAMETER
$                       DEFINES THE TYPE OF CYCLIC SYMMETRY. THE VALUE
$                       OF THIS PARAMETER HAS BEEN SET TO -ROT- FOR
$                       ROTATIONAL SYMMETRY.
$        E. KMAX      - REQUIRED - THE INTEGER VALUE OF THIS PARAMETER
$                       SPECIFIES THE MAXIMUM VALUE OF THE HARMONIC
$                       INDEX. THERE IS NO DEFAULT FOR THIS PARAMETER.
$                       THE MAXIMUM VALUE THAT CAN BE SPECIFIED IS NSEGS/2
$        F. KMIN      - OPTIONAL - THE INTEGER VALUE OF THIS PARAMETER
$                       SPECIFIES THE MINIMUM VALUE OF THE HARMONIC
$                       INDEX TO BE USED IN THE SOLUTION LOOP. KMIN CAN
$                       EQUAL KMAX. THE DEFAULT VALUE IS 0.
$        G. LMAX      - OPTIONAL - THE INTEGER VALUE OF THIS PARAMETER
$                       SPECIFIES THE MAXIMUM TIME HARMONIC INDEX. THE
$                       DEFAULT VALUE IS NTSTEPS/2, WHERE NTSTEPS EQUALS
$                       N (FROM TSTEP CARD) PLUS 2.
$        H. NLOAD     - FIXED    - THE INTEGER VALUE OF THIS PARAMETER
$                       IS THE NUMBER OF LOADING CONDITIONS. THE VALUE
$                       OF THIS PARAMETER IS INTERNALLY CALCULATED.
$        I. RPS       - OPTIONAL - THE REAL VALUE OF THIS PARAMETER
$                       DEFINES THE ROTATIONAL SPEED OF THE STRUCTURE
$                       IN REVOLUTIONS PER UNIT TIME. THE DEFAULT VALUE
$                       IS 0.0 .
$        J. BXTID     - OPTIONAL - THE POSITIVE INTEGER VALUES OF THESE
$           BYTID       PARAMETERS DEFINE THE SET IDENTIFICATION NUMBERS
$           BZTID       OF THE TABLED1 BULK DATA CARDS WHICH DEFINE THE
$           BXPTID      COMPONENTS OF THE BASE ACCELERATION VECTOR. THE
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$           BYPTID     TABLES REFERED TO BY BXTID, BYTID AND BZTID
$           BZPTID     DEFINE MAGNITUDE(LT-2) AND THE TABLES REFERED TO
$                      BY BXPTID, BYPTID AND BZPTID DEFINE PHASE(DEGREE).
$                      THE DEFAULT VALUES ARE -1 WHICH MEANS THAT THE
$                      RESPECTIVE TERMS ARE IGNORED.
$       K. NOKPRT    - OPTIONAL - AN INTEGER VALUE OF &1 FOR THIS
$                      PARAMETER WILL CAUSE THE CURRENT HARMONIC INDEX,
$                      KINDEX, TO BE PRINTED AT THE TOP OF THE HARMONIC
$                      LOOP. THE DEFAULT VALUE IS &1.
$       L. GRDPNT    - OPTIONAL - A POSITIVE INTEGER VALUE OF THIS
$                      PARAMETER WILL CAUSE THE GRID POINT WEIGHT
$                      GENERATOR TO BE EXECUTED AND THE RESULTING WEIGHT
$                      BALANCE INFORMATION TO BE PRINTED. DEFAULT IS -1.
$       M. WTMASS    - OPTIONAL  - THE TERMS OF THE STRUCTURAL MASS
$                      MATRIX ARE MULTIPLIED BY THE REAL VALUE OF THIS
$                      PARAMETER WHEN THEY ARE GENERATED IN EMG. THE
$                      DEFAULT IS 1.0 .
$       N. COUPMASS - FIXED      - ONLY LUMPED MASS MATRICES MUST BE USED.
$       O. GKAD      - OPTIONAL - THE BCD VALUE OF THIS PARAMETER IS
$                      USED TO TELL THE GKAD MODULE THE DESIRED FORM OF
$                      MATRICES KDD, BDD AND MDD. THE BCD VALUE CAN BE
$                      FREQRESP OR TRANRESP. THE DEFAULT IS TRANRESP.
$                      NOTE - REMEMBER TO DEFINE PARAMETERS G, W3 AND W4.
$                             SEE SECTION 9.3.3 (DIRECT DYNAMIC MATRIX
$                             ASSEMBLY) PAGES 9.3-7 AND 9.3-8 OF THE
$                             NASTRAN THEORETICAL MANUAL.
$       P. LGKAD     - OPTIONAL - THE INTEGER VALUE OF THIS PARAMETER
$                      IS USED IN CONJUNCTION WITH PARAMETER GKAD. IF
$                      GKAD=FREQRESP THEN SET LGKAD=1. IF GKAD=TRANRESP
$                      THEN SET LGKAD=-1. THE DEFAULT VALUE IS -1.
$       Q. G         - OPTIONAL - THE REAL VALUE OF THIS PARAMETER IS
$                      USED AS A UNIFORM STRUCTURAL DAMPING COEFFICIENT
$                      IN THE DIRECT FORMULATION OF DYNAMICS PROBLEMS.
$       R. W3        - OPTIONAL - THE REAL VALUE OF THIS PARAMETER IS
$                      USED AS A PIVOTAL FREQUENCY FOR UNIFORM STRUCTUAL
$                      DAMPING IF PARAMETER GKAD=TRANRESP. IN THIS CASE
$                      W3 IS REQUIRED IF UNIFORMED STRUCTUAL DAMPING IS
$                      DESIRED. THE DEFAULT VALUE IS 0.0 .
$       S. W4        - OPTIONAL - THE REAL VALUE OF THIS PARAMETER IS
$                      USED AS A PIVOTAL FREQUENCY FOR ELEMENT STRUCTUAL
$                      DAMPING IF PARAMETER GKAD=TRANRESP. IN THIS CASE
$                      W4 IS REQUIRED IF STRUCTUAL DAMPING IS DESIRED FOR
$                      ANY OF THE STRUCTUAL ELEMENTS. DEFAULT IS  0.0 .
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$ REMARKS -
$    1. THE ANALYSIS WILL LOOP THRU A RANGE OF THE CYCLIC INDEX,
$       KINDEX = KMIN TO KMAX.
$
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$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
ALTER 3 $
FILE      UXVF=APPEND/PDT=APPEND/PD=APPEND $
$ PERFORM INITIAL ERROR CHECKS ON NSEGS AND KMAX.
COND      ERRORC1,NSEGS $  IF USER HAS NOT SPECIFIED NSEGS.
COND      ERRORC1,KMAX  $  IF USER HAS NOT SPECIFIED KMAX.
PARAM     //C,N,EQ /V,N,CYCIOERR /V,Y,CYCIO=0 /C,N,0 $
COND      ERRORC1,CYCIOERR  $  IF USER HAS NOT SPECIFIED CYCIO.
PARAM     //C,N,DIV /V,N,NSEG2 /V,Y,NSEGS /C,N,2 $  NSEG2 = NSEGS/2
PARAM     //C,N,SUB /V,N,KMAXERR /V,N,NSEG2 /V,Y,KMAX $
COND      ERRORC1,KMAXERR $  IF KMAX .GT. NSEGS/2
$ SET DEFAULTS FOR PARAMETERS.
PARAM     //C,N,NOP /V,Y,NOKPRT=61 /V,Y,LGKAD=-1 $
$ CALCULATE OMEGA, 2*OMEGA AND OMEGA**2 FROM RPS. SET DEFAULT RPS.
PARAMR    //C,N,MPY /V,N,OMEGA /V,Y,RPS=0.0 /C,N,6.283185 $
PARAMR    //C,N,MPY /V,N,OMEGA2 /C,N,2.0 /V,N,OMEGA $
PARAMR    //C,N,MPY /V,N,OMEGASQR /V,N,OMEGA /V,N,OMEGA $
$ GENERATE NORPS FLAG IF RPS IS ZERO.
PARAMR    //C,N,EQ //V,Y,RPS /C,N,0.0 ////V,N,NORPS $
$ MAKE SURE COUPLED MASSES HAVE NOT BEEN REQUESTED.
PARAM     //C,N,NOT /V,N,NOLUMP /V,Y,COUPMASS=-1 $
COND      ERRORC2,NOLUMP $
ALTER 21,21 $  ADD SLT TO OUTPUT FOR TRLG.
GP3       GEOM3,EQEXIN,GEOM2 / SLT,GPTT / V,N,NOGRAV $
CHKPNT    SLT,GPTT $
ALTER 23 $
$ SINCE MULTIPLE CONSTRAINTS ARE NOT ALLOWED EXECUTE GP4 NOW SO THAT
$ MORE ERROR CHECKS CAN BE MADE BEFORE ELEMENT GENERATION.
$ ADD YS NEEDED FOR PSF RECOVERY IN SSG2.
PARAM     //C,N,MPY /V,N,NSKIP /C,N,0 /C,N,0 $
GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM/RG,YS,USET,ASET/V,N,LUSET/
          S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,NSKIP/
          S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,AUTOSPC $
PURGE     GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PSF,QPC/SINGLE $
CHKPNT    GM,GMD,RG,GO,GOD,KFS,PSF,QPC,USET,YS $
$ SUPORT BULK DATA IS NOT ALLOWED.
PARAM     //C,N,NOT /V,N,REACDATA /V,N,REACT $
COND      ERRORC3,REACDATA $
$ EXECUTE DPD NOW SO CHECKS CAN BE MADE. ADD TRL TO OUTPUT DATA BLOCKS.
DPD       DYNAMICS,GPL,SIL,USET / GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,
          TRL,,EQDYN / V,N,LUSET/S,N,LUSETD/V,N,NOTFL/S,N,NODLT/
          S,N,NOPSDL/S,N,NOFRL/V,N,NONLFT/S,N,NOTRL/V,N,NOEED/C,N,/
          S,N,NOUE $
$ MUST HAVE EITHER FREQ OR TSTEP BULK DATA.
PARAM     //C,N,AND/V,N,FTERR /V,N,NOFRL /V,N,NOTRL $
COND      ERRORC5,FTERR $  NO FREQ OR TSTEP BULK DATA.
$ ONLY FREQUENCY OR TSTEP IS ALLOWED IN THE CASE CONTROL
PARAML    CASECC //C,N,DTI /C,N,1 /C,N,14 //V,N,FREQSET $
PARAML    CASECC //C,N,DTI /C,N,1 /C,N,38 //V,N,TIMESET $
PARAM     //C,N,MPY /V,N,FREQTIME /V,N,FREQSET /V,N,TIMESET $
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PARAM    //C,N,NOT /V,N,FTERR1 /V,N,FREQTIME $
PARAM    //C,N,LE /V,N,NOFREQ /V,N,FREQSET /C,N,0 $
PARAM    //C,N,LE /V,N,NOTIME /V,N,TIMESET /C,N,0 $
COND     ERRORC6,FTERR1 $  BOTH FREQ AND TSTEP IN CASE CONTROL DECK.
$ EPOINT BULK DATA NOT ALLOWED
PARAM    //C,N,NOT /V,N,EXTRAPTS /V,N,NOUE $
COND     ERRORC4,EXTRAPTS $
$ GENERATE DATA FOR CYCT2 MODULE.
GPCYC    GEOM4,EQDYN,USETD /CYCDD /V,N,CTYPE=ROT /S,N,NOGO $
COND     ERRORC1,NOGO $
CHKPNT   CYCDD $
ALTER 32 $
$ PRE-PURGE DATA BLOCKS THAT WILL NOT BE GENERATED
PARAM    //C,N,OR /V,N,NOBM1 /V,N,NOMGG /V,N,NOKPS $
PURGE    B1GG,M1GG /NOBM1 $
PURGE    M2GG,M2BASEXG /NOMGG $
ALTER 35 $
$ GENERATE DATA BLOCKS FRLX, B1GG, M1GG, M2GG AND BASEGX.
$ GENERATE PARAMETERS FKMAX AND NOBASEX.
DUMMOD1  CASECC,BGPDT,CSTM,DIT,FRL,MGG,, / FRLX,B1GG,M1GG,
         M2GG,BASEXG,PDZERO,, /V,N,NOMGG/V,Y,CYCIO/V,Y,NSEGS/
         V,Y,KMAX/S,N,FKMAX/V,Y,BXTID=-1/V,Y,BXPTID=-1/
         V,Y,BYTID=-1/V,Y,BYPTID=-1/V,Y,BZTID=-1/
         V,Y,BZPTID=-1/S,N,NOBASEX/V,N,NOFREQ/V,N,OMEGA  $
PARAML   FRLX //C,N,PRESENCE ////V,N,NOFRLX $
COND     LBLFRLX,NOFRLX $
EQUIV    FRLX,FRL $
LABEL    LBLFRLX $
CHKPNT   FRL,B1GG,M1GG,M2GG,BASEXG $
ALTER 42 $
PARAM    //C,N,ADD /V,N,NOBGG /V,N,NOBM1 /C,N,0 $  RESET NOBGG.
ALTER 52 $
$ REDEFINE BGG AND KGG.
COND     LBL11A,NOBM1 $
PARAMR   //C,N,COMPLEX // V,N,OMEGA2 / C,N,0.0 / V,N,CMPLX1 $
PARAMR   //C,N,SUB / V,N,MOMEGASQ / C,N,0.0 / V,N,OMEGASQR $
PARAMR   //C,N,COMPLEX // V,N,MOMEGASQ / C,N,0.0 / V,N,CMPLX2 $
ADD      BGG,B1GG / BGG1 / C,N,(1.0,0.0) / V,N,CMPLX1 $
EQUIV    BGG1,BGG $
ADD      KGG,M1GG / KGG1 / C,N,(1.0,0.0) / V,N,CMPLX2 $
EQUIV    KGG1,KGG $
CHKPNT   BGG,KGG $
LABEL    LBL11A
ALTER 53,55 $ GP4 HAS BEEN MOVED-UP.
ALTER 88,88 $ DPD HAS BEEN MOVED-UP.
ALTER 114 $  PARAM AND EQUIV LOGIC DEPENDING ON LGKAD FOR FREQ OR TRAN.
PARAM    //C,N,AND/V,N,KDEKA/V,N,NOUE/V,N,NOK2PP $
COND     LGKAD1,LGKAD $  BRANCH IN NOT FREQRESP.
ALTER 115 $  SEE ALTER 114 COMMENT.
JUMP     LGKAD2 $
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LABEL     LGKAD1 $
EQUIV     M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/
          KAA,KDD/KDEKA $
CHKPNT    K2PP,M2PP,B2PP,K2DD,M2DD,B2DD,KDD,MDD $
LABEL     LGKAD2 $
ALTER 117,117 $ ADD PARAMETERS GKAD, W3 AND W4 TO GKAD.
GKAD      USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
          GOD,K2DD,M2DD,B2DD/C,Y,GKAD=TRANRESP/C,N,DISP/C,N,DIRECT/
          C,Y,G=0.0/C,Y,W3=0.0/C,Y,W4=0.0/V,N,NOK2PP/V,N,NOM2PP/
          V,N,NOB2PP/V,N,MPCF1/V,N,SINGLE/V,N,OMIT/V,N,NOUE/V,N,NOK4GG/
          V,N,NOBGG/V,N,KDEK2/C,N,-1 $
ALTER 118 $  SEE ALTER 114 COMMENT.
COND      LGKAD3,LGKAD $  BRANCH IF NOT FREQRESP.
ALTER 119 $  SEE ALTER 114 COMMENT.
JUMP      LGKAD4 $
LABEL     LGKAD3 $
EQUIV     B2DD,BDD/NOGPDT/M2DD,MDD/NOSIMP/K2DD,KDD/KDEK2 $
LABEL     LGKAD4 $
ALTER 120,123 $
$ NEW SOLUTION LOGIC
$ GENERATE TIME-DEPENDENT LOADS IF TSTEP WAS REQUESTED IN CASE CONTROL.
COND      LBLTRL1,NOTIME $
$ LOOP THRU ALL SUBCASES FOR TIME-DEPENDENT LOADS.
PARAM     //C,N,MPY /V,N,REPEATT /C,N,1 /C,N,-1 $
PARAM     //C,N,ADD /V,N,APPFLG /C,N,1 /C,N,0 $  INITIALIZE FOR SDR1.
JUMP      TRLGLOOP $
LABEL     TRLGLOOP $
CASE      CASECC,/CASEYY/C,N,TRAN/S,N,REPEATT/S,N,NOLOOP1 $
CHKPNT    CASEYY $
PARAM     //C,N,MPY /V,N,NCOL /C,N,0 /C,N,1 $
TRLG      CASEYY,USETD,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GOD,,EST,MGG/
          ,,PDT1,PD1,,TOL/ V,N,NOSET/S,N,PDEPDO/V,N,NCOL $
SDR1      TRL,PDT1,,,,,,,,, / ,PDT, /V,N,APPFLG/C,N,DYNAMICS $
SDR1      TRL,PD1 ,,,,,,,,, / ,PD , /V,N,APPFLG/C,N,DYNAMICS $
PARAM     //C,N,ADD /V,N,APPFLG /V,N,APPFLG /C,N,1 $  APPFLG=APPFLG+1.
COND      TRLGDONE,REPEATT $
REPT      TRLGLOOP,100 $
JUMP      ERROR3 $
LABEL     TRLGDONE $
CHKPNT    PDT,PD,TOL $
EQUIV     PD,PDT/PDEPDO $
CHKPNT    PDT $
DUMMOD2   TOL,,,,,,, / FRLZ,FOLZ,REORDER1,REORDER2,,,, /
          V,Y,NSEGS/V,Y,CYCIO/S,Y,LMAX=-1/V,N,FKMAX/
          S,N,FLMAX/S,N,NTSTEPS/S,N,NORO1/S,N,NORO2 $
EQUIV     FRLZ,FRL // FOLZ,FOL $
CHKPNT    FRL,FOL,REORDER1,REORDER2 $
JUMP      LBLFRL2 $
LABEL     LBLTRL1 $
$ GENERATE FREQUENCY-DEPENDENT LOADS IF FREQUENCY WAS SELECTED IN CC.
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FRLG     CASEXX,USETD,DLT,FRL,GMD,GOD,DIT, / PPF,PSF,PDF,FOL,PHFDUM /
         C,N,DIRECT/V,N,FREQY/C,N,FREQ $
COND     LBLFRLX1,NOFRLX $  ZERO OUT LOAD COLUMNS IF FRLX WAS GENERATED.
MPYAD    PPF,PDZERO, / PPFX /C,N,0 $
EQUIV    PPFX,PPF $
LABEL    LBLFRLX1 $
$ FORM NEW LOADS.
COND     LBLFRL1,NOBASEX $
MPYAD    M2GG,BASEXG, / M2BASEXG /C,N,0 $
ADD      PPF,M2BASEXG / PPF1 /C,N,(1.0,0.0) /C,N,(-1.0,0.0) $
EQUIV    PPF1,PPF $
COND     LBLBASE1,NOSET $
SSG2     USETD,GMD,YS,KFS,GOD,,PPF / ,PODUM1,PSF1,PDF1 $
EQUIV    PSF1,PSF // PDF1,PDF $
LABEL    LBLBASE1 $
LABEL    LBLFRL1 $
EQUIV    PPF,PDF/NOSET $
CHKPNT   PPF,PSF,PDF,FOL $
$ LOADS ARE FREQUENCY-DEPENDENT
$ PERFORM CYCLIC TRANSFORMATION ON LOADS IF CYCIC=&1.
PARAML   PDF //C,N,TRAILER /C,N,1 /V,N,PDFCOLS $
$ CALCULATE THE NUMBER OF LOADS FOR CYCIO=-1.
PARAM    //C,N,DIV /V,N,NLOAD /V,N,PDFCOLS /V,N,FKMAX $ NLOAD = NF/FKMAX
EQUIV    PDF,PXF/CYCIO $
COND     LBLPDONE,CYCIO $
$ CALCULATE THE NUMBER OF LOADS FOR CYCIO=1.
PARAM    //C,N,DIV /V,N,NLOAD /V,N,PDFCOLS /V,Y,NSEGS $ NLOAD = NF/NSEGS
CYCT1    PDF / PXF,GCYCF1 /V,N,CTYPE /C,N,FORE /V,Y,NSEGS=-1 /
         V,Y,KMAX=-1 / V,N,NLOAD /S,N,NOGO $
COND     ERRORC1,NOGO $
CHKPNT   PXF $
JUMP     LBLPDONE $
LABEL    LBLFRL2 $
$ LOADS ARE TIME-DEPENDENT
PARAM    //C,N,NOT /V,N,NOTCYCIO /V,Y,CYCIO $
$ BRANCH DEPENDING ON VALUE OF CYCIC
COND     LBLTRL2,NOTCYCIC $
$ CYCIO=-1
EQUIV    PDT,PDTRZ1/NORO1 $
COND     LBLRO1A,NORO1 $
MPYAD    PDT,REORDER1, / PDTRZ1 / C,N,0 $
LABEL    LBLRO1A $
CYCT1    PDTRZ1 / PXTRZ1,GCYCF2 /V,N,CTYPE/C,N,FORE/V,N,NTSTEPS/
         V,Y,LMAX/V,N,FKMAX/S,N,NOGO $
COND     ERRORC1,NOGO $
CHKPNT   PXTRZ1 $
EQUIV    PXTRZ1,PXFZ1/NORO2 $
COND     LBLRO2A,NORO2 $
MPYAD    PXTRZ1,REORDER2, / PXFZ1 /C,N,0 $
LABEL    LBLRO2A $
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EQUIV     PXFZ1,PXF1 $
CHKPNT    PXF1 $
JUMP      LBLTRL3 $
LABEL     LBLTRL2 $
$ CYCIO = &1
MPYAD     PDT,REORDER1, / PDTR22 / C,N,0 $
CYCT1     PDTR22 /PXTR22,GCYCF3 /V,N,CTYPE/C,N,FORE/V,N,NTSTEPS/V,Y,LMAX/
             V,Y,NSEGS/S,N,NOGO $
COND      ERRORC1,NOGO $
CHKPNT    PXTR22 $
EQUIV     PXTR22,PXTR2/NOR02 $
COND      LBLR02B,NOR02 $
MPYAD     PXTR22,REORDER2, / PXTR2 /C,N,0 $
LABEL     LBLR02B $
CYCT1     PXTR2 / PXFZ2,GCYCF4 / V,N,CTYPE/C,N,FORE/V,Y,NSEGS/V,Y,KMAX/
             V,N,FLMAX/S,N,NOGO $
COND      ERRORC1,NOGO $
EQUIV     PXFZ2,PXF1 $
CHKPNT    PXF1 $
LABEL     LBLTRL3 $
$ TIME-DEPENDENT LOADS ARE REAL. MAKE LOADS COMPLEX TO CORRESPOND
$ TO FREQUENCY DEPENDENT LOADS. ALSO SDR2 EXPECTS LOADS TO BE COMPLEX
$ IN FREQRESP TYPE PROBLEMS.
COPY      PXF1 / PXF2  $  CONVERT REAL PXF1 TO COMPLEX PXF.
ADD       PXF1,PXF2 / PXF / C,N,(0.5,1.0) / C,N,(0.5,-1.0) $
$ DEFINE NLOAD FOR CYCT2.
PARAM     //C,N,ADD /V,N,NLOAD /V,N,FLMAX /C,N,0 $  NLOAD = FLMAX
LABEL     LBLPDONE $
PARAM     //C,N,ADD /V,N,KINDEX /V,Y,KMIN=0 /C,N,0 $  INTITIALIZE KINDEX.
$
$ INITIALIZE UXVF IF KMIN IS NOT ZERO.
$
PARAM     //C,N,ADD /V,N,KMINL /V,Y,KMIN /C,N,-1 $
COND      NOKMINL,KMINL $
PARAM     //C,N,ADD /V,N,KMINV /C,N,0 /C,N,0 $
JUMP      KMINLOOP $
LABEL     KMINLOOP $
CYCT2     CYCDD,,,PXF,, /,,PKF2,, / C,N,FORE/V,Y,NSEGS/
          V,N,KMINV/V,N,CYCSEQ/V,N,NLOAD/S,N,NOGO $
COND      ERRORC1,NOGO $
ADD       PKF2, / UKVF2 / C,N,(0.0,0.0) $
CYCT2     CYCDD,,,UKVF2,, /,,UXVF,, / C,N,BACK/V,Y,NSEGS/
          V,N,KMINV/V,N,CYCSEQ/V,N,NLOAD/S,N,NOGO $
COND      ERRORC1,NOGO $
PARAM     //C,N,ADD /V,N,KMINV /V,N,KMINV /C,N,1 $
REPT      KMINLOOP,KMINL $
LABEL     NOKMINL $
$
JUMP      TOPCYC $
LABEL     TOPCYC $  LOOP ON KINDEX
```

```
COND     NOKPRT,NOKPRT $
PRTPARM  //C,N,0 /C,N,KINDEX $
LABEL    NOKPRT $
CYCT2    CYCDD,KDD,MDD,,, /KKKF,MKKF,,, /C,N,FORE/V,Y,NSEGS /
         V,N,KINDEX/V,N,CYCSEQ=-1/V,N,NLOAD/S,N,NOGC $
COND     ERRORC1,NOGC $
CHKPNT   KKKF,MKKF $
PARAM    //C,N,SYST //C,N,58 /C,N,2 $  METHOD 3T IN CYCT2 PRODUCES
$                                      UNDERFLOWS FOR PXF. USE METHOD 2.
CYCT2    CYCDD,BDD,,PXF,, /BKKF,,PKF,, / C,N,FORE/V,Y,NSEGS/
         V,N,KINDEX/V,N,CYCSEQ/V,N,NLOAD/S,N,NOGC $
PARAM    //C,N,SYST //C,N,58 /C,N,0 $  RESET MPYAD METHOD CONTROL.
COND     ERRORC1,NOGC $
CHKPNT   BKKF,PKF $
$ SOLUTION
FRRD2    KKKF,BKKF,MKKF,,PKF,FOL / UKVF /C,N,0.0/C,N,0.0/C,N,-1.0 $
CHKPNT   UKVF $
CYCT2    CYCDD,,,UKVF,, /,,UXVF,, /C,N,BACK/V,Y,NSEGS/V,N,KINDEX/
         V,N,CYCSEQ/V,N,NLOAD/S,N,NOGC $
COND     ERRORC1,NOGC $
CHKPNT   UXVF $
PARAM    //C,N,ADD /V,N,KINDEX/V,N,KINDEX/C,N,1 $  KINDEX = KINDEX & 1
PARAM    //C,N,SUB /V,N,DONE / V,Y,KMAX / V,N,KINDEX $
COND     LCYC2,DONE $  IF KINDEX .GT. KMAX THEN EXIT
REPT     TOPCYC,1CC $
JUMP     ERROR3 $
LABEL    LCYC2 $
EQUIV    UXVF,UDVF / CYCIO $
CHKPNT   UDVF $
COND     LCYC3,CYCIO $  IF CYCIO .GE. 0 THEN TRANSFORM TO PHYSICAL.
CYCT1    UXVF / UDVF,GCYC01 / V,N,CTYPE/C,N,BACK/V,Y,NSEGS/V,Y,KMAX/
         V,N,NLOAD $
CHKPNT   UDVF $
LABEL    LCYC3 $
COND     LBLTRL4,NOTIME $
EQUIV    PXF,PDF2 / CYCIO $
COND     LCYC4,CYCIO $  IF CYCIO .GE. 0 THEN TRANSFORM TO PHYSICAL.
CYCT1    PXF / PDF2,GCYC02 / V,N,CTYPE/C,N,BACK/V,Y,NSEGS/V,Y,KMAX/
         V,N,NLOAD $
LABEL    LCYC4 $
$ IF LOADS WERE TIME-DEPENDENT THEN RECOVER PPF AND PSF FROM PXF.
SDR1     USETD,,PDF2,,,GOD,GMD,,,, / PPFZ,, /C,N,1 /C,N,DYNAMICS $
SSG2     USETD,GMD,YS,KFS,GOD,,PPFZ / ,PODUM,PSFZ,PLDUM $
EQUIV    PPFZ,PPF // PSFZ,PSF $
CHKPNT   PPF,PSF $
LABEL    LBLTRL4 $
ALTER 124,124 $  USE FOL INSTEAD OF PPF TO GET OUTPUT FREQUENCY LIST.
VDR      CASEXX,EQDYN,USETD,UDVF,FOL,XYCDB,/OUDVC1,/C,N,FREQRESP/C,N,
         DIRECT/S,N,NOSORT2/S,N NCD/S,N,NOP/C,N,0 $
ALTER 140,140 $  USE FOL INSTEAD OF PPF TO GET OUTPUT FREQUENCY LIST.
```

N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

```
SDR2      CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,FLL,QPC,UPVC,EST,XYCDB,
          PPF/OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,PUPVC1/C,N,FREQRESP/
          S,N,NOSORT2 $
ALTER 160  $  ADD LABEL FOR ERROR3.
LABEL     ERROR3 $
ALTER 163,166 $  REMOVE ERROR1 AND ERROR2.
ALTER 168 $ FORCED VIBRATION ERRORS
LABEL     ERRORC1 $  CHECK NSEGS, KMAX AND OTHER CYCLIC DATA.
PRTPARM   //C,N,-7 /C,N,CYCSTATICS $
LABEL     ERRORC2 $  COUPLED MASS NOT ALLOWED.
PRTPARM   //C,N,0 /C,Y,COUPMASS $
JUMP      FINIS $
LABEL     ERRORC3 $  SUPORT BULK DATA NOT ALLOWED.
PRTPARM   //C,N,-6 /C,N,CYCSTATICS $
LABEL     ERRORC4 $  EPOINT BULK DATA NOT ALLOWED.
PRTPARM   //C,N,0 /C,N,NOUE $
JUMP      FINIS $
LABEL     ERRORC5 $  NEITHER FREQ OR TSTEP WERE IN BULK DATA DECK.
PRTPARM   //C,N,0 /C,N,NOFRL $
PRTPARM   //C,N,0 /C,N,NOTRL $
JUMP      FINIS $
LABEL     ERRORC6 $  BOTH FREQ AND TSTEP WERE SELECTED IN CASE CONTROL.
PRTPARM   //C,N,0 /C,N,NOFREQ $
PRTPARM   //C,N,0 /C,N,NOTIME $
JUMP      FINIS $
ENDALTER
```

2.4.2 DMAP Sequence for Forced Vibration Analysis of Rotating Cyclic Structures

```
OPTIONS IN EFFECT   GO       ERR=2    NOLIST  NODECK  NOREF   NOOSCAR
   1  BEGIN     NO.8 FORCED VIBRATIONS OF ROTATING CYCLIC STRUCTURES - SERIES R
   2  PRECHK    ALL $
   3  FILE      KGGX=TAPE/KGG=TAPE/GOD=SAVE/GMD=SAVE/MDD=SAVE/BDD=SAVE $
   4  FILE      UXVF=APPEND/PDT=APPEND/PD=APPEND $
   5  COND      ERRORC1,NSEGS $  IF USER HAS NOT SPECIFIED NSEGS.
   6  COND      ERRORC1,KMAX  $  IF USER HAS NOT SPECIFIED KMAX.
   7  PARAM     //C,N,EQ /V,N,CYCIOERR /V,Y,CYCIO=0 /C,N,0 $
   8  COND      ERRORC1,CYCIOERR  $  IF USER HAS NOT SPECIFIED CYCIO.
   9  PARAM     //C,N,DIV /V,N,NSEG2 /V,Y,NSEGS /C,N,2 $  NSEG2 = NSEGS/2
  10  PARAM     //C,N,SUB /V,N,KMAXERR /V,N,NSEG2 /V,Y,KMAX $
  11  COND      ERRORC1,KMAXERR $  IF KMAX .GT. NSEGS/2
  12  PARAM     //C,N,NOP /V,Y,NOKPRT=&1 /V,Y,LGKAD=-1 $
  13  PARAMR    //C,N,MPY /V,N,OMEGA /V,Y,RPS=0.0 /C,N,6.283185 $
  14  PARAMR    //C,N,MPY /V,N,OMEGA2 /C,N,2.0 /V,N,OMEGA $
  15  PARAMR    //C,N,MPY /V,N,OMEGASQR /V,N,OMEGA /V,N,OMEGA $
  16  PARAMR    //C,N,EQ //V,Y,RPS /C,N,0.0 ////V,N,NORPS $
  17  PARAM     //C,N,NOT /V,N,NOLUMP /V,Y,COUPMASS=-1 $
  18  COND      ERRORC2,NOLUMP $
  19  PARAM     //*MPY*/CARDNO/0/0 $
  20  GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  S,N,
                NOGPDT $
  21  PLTTRAN   BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $
  22  PURGE     USET,GM,GO,KAA,BAA,MAA,K4AA,KFS,PSF,QPC,EST,ECT,PLTSETX,PLTPAR,
                GPSETS,ELSETS/NOGPDT $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
23  COND      LBL5,NOGPDT $
24  GP2       GEOM2,EQEXIN/ECT $
25  PARAML    PCDB//*PRES*////NOPCDB $
26  PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/NOPCDB $
27  COND      P1,NOPCDB $
28  PLTSET    PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/   S,N,
              JUMPPLOT=-1 $
29  PRTMSG    PLTSETX// $
30  PARAM     //*MPY*/PLTFLG/1/1 $
31  PARAM     //*MPY*/PFILE/0/0 $
32  COND      P1,JUMPPLOT $
33  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/
              NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
34  PRTMSG    PLOTX1//$
35  LABEL     P1 $
36  GP3       GEOM3,EQEXIN,GEOM2 / SLT,GPTT / V,N,NOGRAV $
37  CHKPNT    SLT,GPTT $
38  TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP=
              -1/1/S,N,NOGENL=-1/S,N,GENEL $
39  PURGE     K4GG,GPST,OGPST,MGG,BGG,K4NN,K4FF,K4AA,MNN,MFF,MAA,BNN,BFF,BAA,
              KGGX/NOSIMP/OGPST/GENEL $
40  PARAM     //C,N,MPY /V,N,NSKIP /C,N,0 /C,N,0 $
41  GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM/RG,YS,USET,ASET/V,N,LUSET/
              S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,NSKIP/
              S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,AUTOSPC $

42  PURGE     GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PSF,QPC/SINGLE $
43  CHKPNT    GM,GMD,RG,GO,GOD,KFS,PSF,QPC,USET,YS $
```

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
44  PARAM    //C,N,NOT /V,N,REACDATA /V,N,REACT $
45  COND     ERRORC3,REACDATA $
46  DPD      DYNAMICS,GPL,SIL,USET / GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,
             TRL,,EQDYN / V,N,LUSET/S,N,LUSETD/V,N,NOTFL/S,N,NODLT/
             S,N,NOPSDL/S,N,NOFRL/V,N,NONLFT/S,N,NOTRL/V,N,NOEED/C,N,/
             S,N,NOUE $
47  PARAM    //C,N,AND/V,N,FTERR /V,N,NOFRL /V,N,NOTRL $
48  COND     ERRORC5,FTERR $  NO FREQ OR TSTEP BULK DATA.
49  PARAML   CASECC //C,N,DTI /C,N,1 /C,N,14 //V,N,FREQSET $
50  PARAML   CASECC //C,N,DTI /C,N,1 /C,N,38 //V,N,TIMESET $
51  PARAM    //C,N,MPY /V,N,FREQTIME /V,N,FREQSET /V,N,TIMESET $
52  PARAM    //C,N,NOT /V,N,FTERR1 /V,N,FREQTIME $
53  PARAM    //C,N,LE /V,N,NOFREQ /V,N,FREQSET /C,N,0 $
54  PARAM    //C,N,LE /V,N,NOTIME /V,N,TIMESET /C,N,0 $
55  COND     ERRORC6,FTERR1 $  BOTH FREQ AND TSTEP IN CASE CONTROL DECK.
56  PARAM    //C,N,NOT /V,N,EXTRAPTS /V,N,NOUE $
57  COND     ERRORC4,EXTRAPTS $
58  GPCYC    GEOM4,EQDYN,USETD /CYCDD /V,N,CTYPE=ROT /S,N,NOGO $
59  COND     ERRORC1,NOGO $
60  CHKPNT   CYCDD $
61  COND     LBL1,NOSIMP $
62  PARAM    //*ADD*/NOKGGX/1/0 $
63  PARAM    //*ADD*/NOMGG/1/0 $
64  PARAM    //*ADD*/NOBGG=-1/1/0 $
65  PARAM    //*ADD*/NOK4GG/1/0 $
66  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,BELM,BDICT/   S,
             N,NOKGGX/S,N,NOMGG/S,N,NOBGG/S,N,NOK4GG//C,Y,COUPMASS/C,Y,
             CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
              CPTRIA2/C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $
67  COND      LBLKGGX,NOKGGX $
68  EMA       GPECT,KDICT,KELM/KGGX,GPST $
69  LABEL     LBLKGGX $
70  PARAM     //C,N,OR /V,N,NOBMI /V,N,NOMGG /V,N,NORPS $
71  PURGE     BIGG,MIGG /NOBMI $
72  PURGE     M2GG,M2BASEXG /NOMGG $
73  COND      LBLMGG,NOMGG $
74  EMA       GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
75  LABEL     LBLMGG $
76  DUMMOD1   CASECC,BGPDT,CSTM,DIT,FRL,MGG,, / FRLX,BIGG,MIGG,
              M2GG,BASEXG,PDZERO,, /V,N,NOMGG/V,Y,CYCIO/V,Y,NSEGS/
              V,Y,KMAX/S,N,FKMAX/V,Y,BXTID=-1/V,Y,BXPTID=-1/
              V,Y,BYTID=-1/V,Y,BYPTID=-1/V,Y,BZTID=-1/
              V,Y,BZPTID=-1/S,N,NOBASEX/V,N,NOFREQ/V,N,OMEGA  $
77  PARAML    FRLX //C,N,PRESENCE ////V,N,NOFRLX $
78  COND      LBLFRLX,NOFRLX $
79  EQUIV     FRLX,FRL $
80  LABEL     LBLFRLX $
81  CHKPNT    FRL,BIGG,MIGG,M2GG,BASEXG $
82  COND      LBLBGG,NOBGG $
83  EMA       GPECT,BDICT,BELM/BGG, $
84  LABEL     LBLBGG $
85  COND      LBLK4GG,NOK4GG $
86  EMA       GPECT,KDICT,KELM/K4GG,/NOK4GG $
87  LABEL     LBLK4GG $
88  PURGE     MNN,MFF,MAA/NOMGG $
```

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
 89  PARAM     //C,N,ADD /V,N,NOBGG /V,N,NOBM1 /C,N,0 $  RESET NOBGG.
 90  PURGE     BNN,BFF,BAA/NOBGG $
 91  COND      LBL1,GRDPNT $
 92  COND      ERROR4,NOMGG $
 93  GPWG      BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
 94  OFP       OGPWG,,,,,//S,N,CARDNO $
 95  LABEL     LBL1 $
 96  EQUIV     KGGX,KGG/NOGENL $
 97  COND      LBL11,NOGENL $
 98  SMA3      GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $
 99  LABEL     LBL11 $
100  COND      LBL11A,NOBM1 $
101  PARAMR    //C,N,COMPLEX // V,N,OMEGA2 / C,N,0.0 / V,N,CMPLX1 $
102  PARAMR    //C,N,SUB / V,N,MOMEGASQ / C,N,0.0 / V,N,CMEGASQR $
103  PARAMR    //C,N,COMPLEX // V,N,MOMEGASQ / C,N,0.0 / V,N,CMPLX2 $
104  ADD       BGG,B1GG / BGG1 / C,N,(1.0,0.0) / V,N,CMPLX1 $
105  EQUIV     BGG1,BGG $
106  ADD       KGG,M1GG / KGG1 / C,N,(1.0,0.0) / V,N,CMPLX2 $
107  EQUIV     KGG1,KGG $
108  CHKPNT    BGG,KGG $
109  LABEL     LBL11A
110  COND      LBL4,GENEL $
111  COND      LBL4,NOSIMP $
112  PARAM     //*EQ*/GPSPFLG/AUTOSPC/0 $
113  COND      LBL4,GPSPFLG $
```

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
COND    LBL4,NOGPST $
OFP     OGPST,,,,,//S,N,CARDNO $
LABEL   LBL4 $
EQUIV   KGG,KNN/MPCF1/MGG,MNN/MPCF1/ BGG,BNN/MPCF1/K4GG,K4NN/MPCF1 $
COND    LBL2,MPCF1 $
MCE1    USET,RG/GM $
MCE2    USET,GM,KGG,MGG,BGG,K4GG/KNN,MNN,BNN,K4NN $
LABEL   LBL2 $
EQUIV   KNN,KFF/SINGLE/MNN,MFF/SINGLE/BNN,BFF/SINGLE/K4NN,K4FF/SINGLE $
COND    LBL3,SINGLE $
SCE1    USET,KNN,MNN,BNN,K4NN/KFF,KFS,,MFF,BFF,K4FF $
LABEL   LBL3 $
EQUIV   KFF,KAA/OMIT $
EQUIV   MFF,MAA/OMIT $
EQUIV   BFF,BAA/OMIT $
EQUIV   K4FF,K4AA/OMIT $
COND    LBL5,OMIT $
SMP1    USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
COND    LBLM,NOMGG $
SMP2    USET,GO,MFF/MAA $
LABEL   LBLM $
COND    LBLB,NOBGG $
SMP2    USET,GO,BFF/BAA $
LABEL   LBLB $
```

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
139  COND     LBL5,NOK4GG $
140  SMP2     USET,GO,K4FF/K4AA $
141  LABEL    LBL5 $
142  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $
143  PARAM    //*ADD*/NEVER/1/0 $
144  PARAM    //*MPY*/REPEATF/-1/1 $
145  BMG      MATPOOL,BGPDT,EQEXIN,CSTM/BDPOOL/S,N,NOKBFL/S,N,NOABFL/ S,N,
              MFACT $
146  PARAM    //*AND*/NOFL/NOABFL/NOKBFL $
147  PURGE    KBFL/NOKBFL/ ABFL/NOABFL $
148  COND     LBLFL3,NOFL $
149  MTRXIN,  ,BDPOOL,EQDYN,,/ABFL,KBFL,/LUSETD/S,N,NOABFL/S,N,NOKBFL/0 $
150  LABEL    LBLFL3 $
151  JUMP     LBL13 $
152  LABEL    LBL13 $
153  PURGE    OUDVC1,OUDVC2,XYPLTFA,UPPC1,OQPC1,OUPVC1,OESC1,OEFC1,UPPC2,
              OQPC2,OUPVC2,OESC2,OEFC2,XYPLTF,PSDF,AUTO,XYPLTR,    K2PP,M2PP,
              B2PP,K2DD,M2DD,B2DD/NEVER $
154  CASE     CASECC,PSDL/CASEXX/*FREQ*/S,N,REPEATF/S,N,NOLOOP $
155  MTRXIN   CASEXX,MATPOOL,EQDYN,,TFPOOL/K2DPP,M2DPP,B2PP/LUSETD/S,N,
              NOK2DPP/S,N,NOM2DPP/S,N,NOB2PP $
156  PARAM    //*AND*/NOM2PP/NOABFL/NOM2DPP $
157  PARAM    //*AND*/NOK2PP/NOFL /NOK2DPP $
158  EQUIV    M2DPP,M2PP/NOABFL $
159  ADD5     ABFL,KBFL,K2DPP,,/K2PP/(-1.0,0.0) $
160  COND     LBLFL2,NOABFL $
161  TRNSP    ABFL/ABFLT $
```

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
162  ADD      ABFLT,M2DPP/M2PP/MFACT $
163  LABEL    LBLFL2 $
164  PARAM    //*AND*/BDEBA/NOUE/NOB2PP $
165  PARAM    //*AND*/KDEK2/NOGENL/NOSIMP $
166  PARAM    //*AND*/MDEMA/NOUE/NOM2PP $
167  PURGE    K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $
168  PARAM    //C,N,AND/V,N,KDEKA/V,N,NOUE/V,N,NOK2PP $
169  COND     LGKAD1,LGKAD $  BRANCH IN NOT FREQRESP.
170  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/BAA,
              BDD/BDEBA $
171  JUMP     LGKAD2 $
172  LABEL    LGKAD1 $
173  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/
              KAA,KDD/KDEKA $
174  CHKPNT   K2PP,M2PP,B2PP,K2DD,M2DD,B2DD,KDD,MDD $
175  LABEL    LGKAD2 $
176  COND     LBL18,NOGPDT $
177  GKAD     USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
              GOD,K2DD,M2DD,B2DD/C,Y,GKAD=TRANRESP/C,N,DISP/C,N,DIRECT/
              C,Y,G=0.0/C,Y,W3=0.0/C,Y,W4=0.0/V,N,NOK2PP/V,N,NOM2PP/
              V,N,NOB2PP/V,N,MPCF1/V,N,SINGLE/V,N,OMIT/V,N,NOUE/V,N,NOK4GG/
              V,N,NOBGG/V,N,KDEK2/C,N,-1 $
178  LABEL    LBL18 $
179  COND     LGKAD3,LGKAD $  BRANCH IF NOT FREQRESP.
180  EQUIV    B2DD,BDD/NOBGG/ M2DD,MDD/NOSIMP/ K2DD,KDD/KDEK2 $
181  JUMP     LGKAD4 $
182  LABEL    LGKAD3 $
183  EQUIV    B2DD,BDD/NOGPDT/M2DD,MDD/NOSIMP/K2DD,KDD/KDEK2 $
```

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
184  LABEL     LGKAD4 $
185  COND      LBLTRL1,NOTIME $
186  PARAM     //C,N,MPY /V,N,REPEATT /C,N,1 /C,N,-1 $
187  PARAM     //C,N,ADD /V,N,APPFLG /C,N,1 /C,N,0 $  INITIALIZE FOR SDR1.
188  JUMP      TRLGLOOP $
189  LABEL     TRLGLOOP $
190  CASE      CASECC,/CASEYY/C,N,TRAN/S,N,REPEATT/S,N,NCLOOP1 $
191  CHKPNT    CASEYY $
192  PARAM     //C,N,MPY /V,N,NCOL /C,N,0 /C,N,1 $
193  TRLG      CASEYY,USETD,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GOD,,EST,MGG/
               ,,PDT1,PD1,,TOL/ V,N,NOSET/S,N,PDEPDO/V,N,NCOL $
194  SDR1      TRL,PDT1,,,,,,,,, / ,PDT, /V,N,APPFLG/C,N,DYNAMICS $
195  SDR1      TRL,PD1 ,,,,,,,,, / ,PD , /V,N,APPFLG/C,N,DYNAMICS $
196  PARAM     //C,N,ADD /V,N,APPFLG /V,N,APPFLG /C,N,1 $  APPFLG=APPFLG&1.
197  COND      TRLGDONE,REPEATT $
198  REPT      TRLGLOOP,100 $
199  JUMP      ERROR3 $
200  LABEL     TRLGDONE $
201  CHKPNT    PDT,PD,TOL $
202  EQUIV     PD,PDT/PDEPDO $
203  CHKPNT    PDT $
204  DUMMOD2   TOL,,,,,,, / FRLZ,FOLZ,REORDER1,REORDER2,,,, /
               V,Y,NSEGS/V,Y,CYCIO/S,Y,LMAX=-1/V,N,FKMAX/
               S,N,FLMAX/S,N,NTSTEPS/S,N,NORO1/S,N,NORO2 $
205  EQUIV     FRLZ,FRL // FOLZ,FOL $
206  CHKPNT    FRL,FOL,REORDER1,REORDER2 $
207  JUMP      LBLFRL2 $
```

```
LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

208  LABEL    LBLTRL1 $
209  FRLG     CASEXX,USETD,DLT,FRL,GMD,GOD,DIT, / PPF,PSF,PDF,FOL,PHFDUM /
              C,N,DIRECT/V,N,FREQY/C,N,FREQ $
210  COND     LBLFRLX1,NOFRLX $  ZERO OUT LOAD COLUMNS IF FRLX HAS GENERATED.
211  MPYAD    PPF,PDZERO, / PPFX /C,N,0 $
212  EQUIV    PPFX,PPF $
213  LABEL    LBLFRLX1 $
214  COND     LBLFRL1,NOBASEX $
215  MPYAD    M2GG,BASEXG, / M2BASEXG /C,N,0 $
216  ADD      PPF,M2BASEXG / PPF1 /C,N,(1.0,0.0) /C,N,(-1.0,0.0) $
217  EQUIV    PPF1,PPF $
218  COND     LBLBASE1,NOSET $
219  SSG2     USETD,GMD,YS,KFS,GOD,,PPF / ,PODUM1,PSF1,PDF1 $
220  EQUIV    PSF1,PSF // PDF1,PDF $
221  LABEL    LBLBASE1 $
222  LABEL    LBLFRL1 $
223  EQUIV    PPF,PDF/NOSET $
224  CHKPNT   PPF,PSF,PDF,FOL $
225  PARAML   PDF //C,N,TRAILER /C,N,1 /V,N,PDFCOLS $
226  PARAM    //C,N,DIV /V,N,NLOAD /V,N,PDFCOLS /V,N,FKMAX $ NLOAD = NF/FKMAX
227  EQUIV    PDF,PXF/CYCIO $
228  COND     LBLPDONE,CYCIO $
229  PARAM    //C,N,DIV /V,N,NLOAD /V,N,PDFCOLS /V,Y,NSEGS $ NLOAD = NF/NSEGS
230  CYCT1    PDF / PXF,GCYCF1 /V,N,CTYPE /C,N,FORE /V,Y,NSEGS=-1 /
              V,Y,KMAX=-1 / V,N,NLOAD /S,N,NOGO $
231  COND     ERRORC1,NOGO $
```

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
232  CHKPNT   PXF $
233  JUMP     LBLPDONE $
234  LABEL    LBLFRL2 $
235  PARAM    //C,N,NOT /V,N,NOTCYCIO /V,Y,CYCIO $
236  COND     LBLTRL2,NOTCYCIO $
237  EQUIV    PDT,PDTRZ1/NCRO1 $
238  COND     LBLRO1A,NORO1 $
239  MPYAD    PDT,REORDER1, / PDTRZ1 / C,N,0 $
240  LABEL    LBLRO1A $
241  CYCT1    PDTRZ1 / PXTRZ1,GCYCF2 /V,N,CTYPE/C,N,FORE/V,N,NTSTEPS/
              V,Y,LMAX/V,N,FKMAX/S,N,NOGO $
242  COND     ERRORC1,NOGO $
243  CHKPNT   PXTRZ1 $
244  EQUIV    PXTRZ1,PXFZ1/NORO2 $
245  COND     LBLPO2A,NORC2 $
246  MPYAD    PXTRZ1,REORDER2, / PXFZ1 /C,N,0 $
247  LABEL    LBLRO2A $
248  EQUIV    PXFZ1,PXF1 $
249  CHKPNT   PXF1 $
250  JUMP     LBLTRL3 $
251  LABEL    LBLTRL2 $
252  MPYAD    PDT,REORDER1, / PDTRZ2 / C,N,0 $
253  CYCT1    PDTRZ2 /PXTP22,GCYCF3 /V,N,CTYPE/C,N,FCRE/V,N,NTSTEPS/V,Y,LMAX/
                  V,Y,NSEGS/S,N,NOGO $
254  COND     ERRORC1,NOGO $
255  CHKPNT   PXTRZ2 $
```

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
256  EQUIV    PXTRZ2,PXTR2/NORO2 $
257  COND     LBLRO28,NORO2 $
258  MPYAD    PXTRZ2,REORDER2, / PXTR2 /C,N,0 $
259  LABEL    LBLRO28 $
260  CYCT1    PXTR2 / PXFZ2,GCYCF4 / V,N,CTYPE/C,N,FORE/V,Y,NSEGS/V,Y,KMAX/
                    V,N,FLMAX/S,N,NOGO $
261  COND     ERRORC1,NOGO $
262  EQUIV    PXFZ2,PXF1 $
263  CHKPNT   PXF1 $
264  LABEL    LBLTRL3 $
265  COPY     PXF1 / PXF2  $  CONVERT REAL PXF1 TO COMPLEX PXF.
266  ADD      PXF1,PXF2 / PXF / C,N,(0.5,1.0) / C,N,(0.5,-1.0) $
267  PARAM    //C,N,ADD /V,N,NLOAD /V,N,FLMAX /C,N,0 $  NLOAD = FLMAX
268  LABEL    LBLPDONE $
269  PARAM    //C,N,ADD /V,N,KINDEX /V,Y,KMIN=0 /C,N,0 $  INITIALIZE KINDEX.
270  PARAM    //C,N,ADD /V,N,KMINL /V,Y,KMIN /C,N,-1 $
271  COND     NOKMINL,KMINL $
272  PARAM    //C,N,ADD /V,N,KMINV /C,N,0 /C,N,0 $
273  JUMP     KMINLOOP $
274  LABEL    KMINLOOP $
275  CYCT2    CYCDD,,,PXF,, /,,PKFZ,, / C,N,FORE/V,Y,NSEGS/
              V,N,KMINV/V,N,CYCSEQ/V,N,NLOAD/S,N,NOGO $
276  COND     ERRORC1,NOGO $
277  ADD      PKFZ, / UKVFZ / C,N,(0.0,0.0) $
278  CYCT2    CYCDD,,,UKVFZ,, /,,UXVF,, / C,N,BACK/V,Y,NSEGS/
              V,N,KMINV/V,N,CYCSEQ/V,N,NLOAD/S,N,NOGO $
279  COND     ERRORC1,NOGO $
```

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
280  PARAM    //C,N,ADD /V,N,KMINV /V,N,KMINV /C,N,1 $
281  REPT     KMINLOOP,KMINL $
282  LABEL    NOKMINL $
283  JUMP     TOPCYC $
284  LABEL    TOPCYC $  LOOP ON KINDEX
285  COND     NOKPRT,NOKPRT $
286  PRTPARM  //C,N,0 /C,N,KINDEX $
287  LABEL    NOKPRT $
288  CYCT2    CYCDD,KDD,MDD,,, /KKKF,MKKF,,, /C,N,FORE/V,Y,NSEGS /
              V,N,KINDEX/V,N,CYCSEQ=-1/V,N,NLOAD/S,N,NOGO $
289  COND     ERRORC1,NOGO $
290  CHKPNT   KKKF,MKKF $
291  PARAM    //C,N,SYST //C,N,58 /C,N,2 $  METHOD 3T IN CYCT2 PRODUCES
292  CYCT2    CYCDD,BDD,,PXF,, /BKKF,,PKF,, / C,N,FORE/V,Y,NSEGS/
              V,N,KINDEX/V,N,CYCSEQ/V,N,NLOAD/S,N,NOGO $
293  PARAM    //C,N,SYST //C,N,58 /C,N,0 $  RESET MPYAD METHOD CONTROL.
294  COND     ERRORC1,NOGO $
295  CHKPNT   BKKF,PKF $
296  FRRD2    KKKF,BKKF,MKKF,,PKF,FOL / UKVF /C,N,0.0/C,N,0.0/C,N,-1.0 $
297  CHKPNT   UKVF $
298  CYCT2    CYCDD,,,UKVF,, /,,UXVF,, /C,N,BACK/V,Y,NSEGS/V,N,KINDEX/
              V,N,CYCSEQ/V,N,NLOAD/S,N,NOGO $
299  COND     ERRORC1,NOGO $
300  CHKPNT   UXVF $
301  PARAM    //C,N,ADD /V,N,KINDEX/V,N,KINDEX/C,N,1 $  KINDEX = KINDEX & 1
302  PARAM    //C,N,SUB /V,N,DONE / V,Y,KMAX / V,N,KINDEX $
303  COND     LCYC2,DONE $  IF KINDEX .GT. KMAX THEN EXIT
```

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OF POOR QUALITY


```
304  REPT     TOPCYC,100 $
305  JUMP     ERROR3 $
306  LABEL    LCYC2 $
307  EQUIV    UXVF,UDVF / CYCIO $
308  CHKPNT   UDVF $
309  COND     LCYC3,CYCIO $  IF CYCIO .GE. 0 THEN TRANSFORM TO PHYSICAL.
310  CYCT1    UXVF / UDVF,GCYCB1 / V,N,CTYPE/C,N,BACK/V,Y,NSEGS/V,Y,KMAX/
              V,N,NLOAD $
311  CHKPNT   UDVF $
312  LABEL    LCYC3 $
313  COND     LBLTRL4,NOTIME $
314  EQUIV    PXF,PDF2 / CYCIO $
315  COND     LCYC4,CYCIO $  IF CYCIO .GE. 0 THEN TRANSFORM TO PHYSICAL.
316  CYCT1    PXF / PDF2,GCYCB2 / V,N,CTYPE/C,N,BACK/V,Y,NSEGS/V,Y,KMAX/
              V,N,NLOAD $
317  LABEL    LCYC4 $
318  SDR1     USETD,,PDF2,,,GOD,GMD,,,, / PPFZ,, /C,N,1 /C,N,DYNAMICS $
319  SSG2     USETD,GMD,YS,KFS,GOD,,PPFZ / ,PODUM,PSFZ,PLDUM $
320  EQUIV    PPFZ,PPF // PSFZ,PSF $
321  CHKPNT   PPF,PSF $
322  LABEL    LBLTRL4 $
323  VDR      CASEXX,EQDYN,USETD,UDVF,FOL,XYCDB,/OUDVC1,/C,N,FREQRESP/C,N,
              DIRECT/S,N,NOSORT2/S,N,NOD/S,N,NOP/C,N,0 $
324  COND     LBL15,NOD $
325  COND     LBL15A,NOSORT2 $
326  SDR3     OUDVC1,,,,,/OUDVC2,,,,, $
327  OFP      OUDVC2,,,,,//S,N,CARDNO $
```

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
328  XYTRAN   XYCDB,OUDVC2,,,,/XYPLTFA/*FREQ*/*DSET*/S,N,PFILE/S,N,CARDNO $
329  XYPLOT   XYPLTFA// $
330  JUMP     LBL15 $
331  LABEL    LBL15A $
332  OFP      OUDVC1,,,,,//S,N,CARDNO $
333  LABEL    LBL15 $
334  COND     LBL20,NOP $
335  EQUIV    UDVF,UPVC/NOA $
336  COND     LBL19,NOA $
337  SDR1     USETD,,UDVF,,,GOD,GMD,PSF,KFS,,/UPVC,,QPC/1/*DYNAMICS* $
338  LABEL    LBL19 $
339  SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,FOL,QPC,UPVC,EST,XYCDB,
              PPF/OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,PUPVC1/C,N,FREQRESP/
              S,N,NOSORT2 $
340  COND     LBL17,NOSORT2 $
341  SDR3     OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,/OPPC2,OQPC2,OUPVC2,OESC2,
              OEFC2, $
342  OFP      OPPC2,OQPC2,OUPVC2,OEFC2,OESC2,//S,N,CARDNO $
343  XYTRAN   XYCDB,OPPC2,OQPC2,OUPVC2,OESC2,OEFC2/XYPLTF/*FREQ*/*PSET*/    S,
              N,PFILE/S,N,CARDNO $
344  XYPLOT   XYPLTF// $
345  COND     LBL16,NOPSDL $
346  RANDOM   XYCDB,DIT,PSDL,OUPVC2,OPPC2,OQPC2,OESC2,OEFC2,CASEXX/PSDF,AUTO/
              S,N,NORD $
347  COND     LBL16,NORD $
348  XYTRAN   XYCDB,PSDF,AUTO,,,/XYPLTR/*RAND*/*PSET*/S,N,PFILE/    S,N,
              CARDNO $
349  XYPLOT   XYPLTR// $
```

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
350  JUMP      LBL16 $
351  LABEL     LBL17 $
352  OFP       OUPVC1,OPPC1,OQPC1,OEFC1,OESC1,//S,N,CARDNO $
353  LABEL     LBL16 $
354  COND      LBL20,JUMPPLOT $
355  PLOT      PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUPVC1,  GPECT,
               OESC1/PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/  S,N,PFILE $
356  PRTMSG    PLOTX2// $
357  LABEL     LBL20 $
358  COND      FINIS,REPEATF $
359  REPT      LBL13,100 $
360  LABEL     ERROR3 $
361  PRTPARM   //-3/*DIRFRRD* $
362  JUMP      FINIS $
363  LABEL     ERROR4 $
364  PRTPARM   //-4/*DIRFRRD* $
365  LABEL     ERRORC1 $  CHECK NSEGS, KMAX AND OTHER CYCLIC DATA.
366  PRTPARM   //C,N,-7 /C,N,CYCSTATICS $
367  LABEL     ERRORC2 $  COUPLED MASS NOT ALLOWED.
368  PRTPARM   //C,N,0 /C,Y,COUPMASS $
369  JUMP      FINIS $
370  LABEL     ERRORC3 $  SUPORT BULK DATA NOT ALLOWED.
371  PRTPARM   //C,N,-6 /C,N,CYCSTATICS $
372  LABEL     ERRORC4 $  EPOINT BULK DATA NOT ALLOWED.
373  PRTPARM   //C,N,0 /C,N,NOUE $
374  JUMP      FINIS $
```

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
LABEL     ERRORC5 $  NEITHER FREQ OR TSTEP WERE IN BULK DATA DECK.
PRTPARM   //C,N,0 /C,N,NOFRL $
PRTPARM   //C,N,0 /C,N,NCTRL $
JUMP      FINIS $
LABEL     ERRORC6 $  BOTH FREQ AND TSTEP WERE SELECTED IN CASE CONTROL.
PRTPARM   //C,N,0 /C,N,NOFREQ $
PRTPARM   //C,N,0 /C,N,NOTIME $
JUMP      FINIS $
LABEL     FINIS $
END       $
```

2.4.3 Description of DMAP Operations for Forced Vibration Analysis of Rotating Cyclic Structures

5. Go to DMAP No. 365 if user has not specified parameter NSEGS.

6. Go to DMAP No. 365 if user has not specified parameter KMAX.

8. Go to DMAP No. 365 if user has not specified parameter CYCIO.

11. Go to DMAP No. 365 if KMAX > NSEGS/2.

18. Go to DMAP No. 367 if user has requested consistent mass.

20. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables to relate internal to external grid point numbers.

23. Go to DMAP No. 141 if only Direct Matrix Input.

24. GP2 generates Element Connection Table with internal indices.

27. Go to DMAP No. 35 if no plot output is requested.

28. PLTSET transforms user input into a form used to drive structure plotter.

29. PRTMSG prints error messages associated with structure plotter.

32. Go to DMAP No. 35 if no undeformed structure plots are requested.

33. PLØT generates all requested undeformed structure plots.

34. PRTMSG prints plotter data and engineering data for each undeformed plot generated.

36. GP3 generates Grid Point Temperature Table.

38. TA1 generates element tables for use in matrix assembly and stress recovery.

41. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations $[R_g]\{u_g\} = 0$.

45. Go to DMAP No. 370 and print error message if free-body supports are present.

46. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating internal and external grid point numbers, including extra points introduced for dynamic analysis, and prepares Transfer Function Pool, Dynamics Load Table, Power Spectral Density List and Frequency Response List.

48. Go to DMAP No. 375 and print parameters NOFRL and NOTRL if there was no FREQ or TSTEP bulk data.

55. Go to DMAP No. 379 and print parameters NOFREQ and NOTIME if both FREQUENCY and TSTEP were requested in the Case Control deck.

57. Go to DMAP No. 372 and print parameter NOUE if extra points are present.

58. GPCYC prepares segment boundary table (CYCDD).

59. Go to DMAP No. 365 and print error message if CYJOIN data is inconsistent.

61. Go to DMAP No. 95 if there are no structural elements.

66. EMG generates structural element stiffness, mass, and damping matrix tables and dictionaries for later assembly.

67. Go to DMAP No. 69 if no stiffness matrix is to be assembled.

68. EMA assembles stiffness matrix $[K^x_{gg}]$ and Grid Point Singularity Table.

73. Go to DMAP No. 75 if no mass matrix is to be assembled.

74. EMA assembles mass matrix $[M_{gg}]$.

76. DUMMOD1 generates modified Frequency Response List, FRLX, Coriolis acceleration coefficient matrix $[B1GG_{gg}]$, centripetal coefficient matrix $[M1GG_{gg}]$, Base acceleration coefficient matrix $[M2GG_{gg}]$, Base acceleration matrix $[BASEXG^F_g]$ and load modification matrix, $[PDZERO^F_g]$, for base acceleration problems.

79. Equivalence FRLX to FRL if FRLX was generated by DUMMOD1.

82. Go to DMAP No. 84 if no viscous damping matrix is to be assembled.

83. EMA assembles viscous damping matrix $[B_{gg}]$.

85. Go to DMAP No. 87 if no structural damping matrix is to be assembled.

86. EMA assembles structural damping matrix $[K^4_{gg}]$.

91. Go to DMAP No. 95 if no weight and balance is requested.

92. Go to DMAP No. 363 and print error message if no mass matrix exists.

93. GPWG generates weight and balance information.

94. ØFP formats weight and balance information prepared by GPWG and places it on the system output file for printing.

96. Equivalence $[K^x_{gg}]$ to $[K_{gg}]$ if no general elements.

97. Go to DMAP No. 99 if no general elements.

98. SMA3 adds general elements to $[K^x_{gg}]$ to obtain stiffness matrix $[K_{gg}]$.

100. Go to DMAP No. 109 if parameter RPS = 0.0 or if no mass matrix is present.

104. ADD assembles the Coriolis acceleration matrix into the viscous damping matrix

$$[BGG1_{gg}] = [B_{gg}] + (4\pi \cdot RPS)\ [B1GG_{gg}]$$

105. Equivalence $[BGG1_{gg}]$ to $[B_{gg}]$.

106. ADD assembles the centripetal acceleration matrix into the stiffness matrix.

$$[KGG1_{gg}] = [K_{gg}] - (2\pi . RPS)^2 \, [M1GG_{gg}]$$

107. Equivalence $[KGG1_{gg}]$ to $[K_{gg}]$.

110. Go to DMAP No. 117 if general elements present.

111. Go to DMAP No. 117 if no structural elements.

114. GPSP determines if possible grid point singularities remain.

115. Go to DMAP No. 117 if no grid point singularities exist.

116. ØFP formats the table of possible grid point singularities prepared by GPSP and places it on the system output file for printing.

118. Equivalence $[K_{gg}]$ to $[K_{nn}]$, $[M_{gg}]$ to $[M_{nn}]$, $[B_{gg}]$ to $[B_{nn}]$ and $[K^4_{gg}]$ to $[K^4_{nn}]$ if no multipoint constraints.

119. Go to DMAP No. 122 if MCE1 and MCE2 have already been executed for current set of multipoint constraints.

120. MCE1 partitions multipoint constraint equations $[R_g] = [R_m \,|\, R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

121. MCE2 partitions stiffness, mass and damping matrices

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right] , \quad [M_{gg}] = \left[\begin{array}{c|c} \bar{M}_{nn} & M_{nm} \\ \hline M_{mn} & M_{mm} \end{array}\right]$$

$$[B_{gg}] = \left[\begin{array}{c|c} \bar{B}_{nn} & B_{nm} \\ \hline B_{mn} & B_{mm} \end{array}\right] , \quad [K^4_{gg}] = \left[\begin{array}{c|c} \bar{K}^4_{nn} & K^4_{nm} \\ \hline K^4_{mn} & K^4_{mm} \end{array}\right]$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G^T_m][K_{mn}] + [K^T_{mn}][G_m] + [G^T_m][K_{mm}][G_m],$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G^T_m][M_{mn}] + [M^T_{mn}][G_m] + [G^T_m][M_{mm}][G_m],$$

$$[B_{nn}] = [\bar{B}_{nn}] + [G^T_m][B_{mn}] + [B^T_{mn}][G_m] + [G^T_m][B_{mm}][G_m],$$

$$[K^4_{nn}] = [\bar{K}^4_{nn}] + [G^T_m][K^4_{mn}] + [K^4_{mn}]^T[G_m] + [G^T_m][K^4_{mm}][G_m].$$

123. Equivalence $[K_{nn}]$ to $[K_{ff}]$, $[M_{nn}]$ to $[M_{ff}]$, $[B_{nn}]$ to $[B_{ff}]$ and $[K^4_{nn}]$ to $[K^4_{ff}]$ if no singlepoint constraints.

124. Go to DMAP No. 126 if no single-point constraints.

125. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] , \quad [M_{nn}] = \left[\begin{array}{c|c} M_{ff} & M_{fs} \\ \hline M_{sf} & M_{ss} \end{array}\right] ,$$

$$[B_{nn}] = \left[\begin{array}{c|c} B_{ff} & B_{fs} \\ \hline B_{sf} & B_{ss} \end{array}\right] \quad \text{and} \quad [K^4_{nn}] = \left[\begin{array}{c|c} K^4_{ff} & K^4_{fs} \\ \hline K^4_{sf} & K^4_{ss} \end{array}\right]$$

127. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates.

128. Equivalence $[M_{ff}]$ to $[M_{aa}]$ if no omitted coordinates.

129. Equivalence $[B_{ff}]$ to $[B_{aa}]$ if no omitted coordinates.

130. Equivalence $[K^4_{ff}]$ to $[K^4_{aa}]$ if no omitted coordinates.

131. Go to DMAP No. 141 if no omitted coordinates.

132. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \left[\begin{array}{c|c} K_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right]$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$
and performs matrix reduction

$$[K^1_{aa}] = [K_{aa}] + [K_{ao}][G_o].$$

133. Go to DMAP No. 135 if n' mass matrix.

134. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \left[\begin{array}{c|c} M_{aa} & M_{ao} \\ \hline M_{oa} & M_{oo} \end{array}\right]$$

and performs matrix reduction

$$[M^1_{aa}] = [M_{aa}] + [M_{ao}][G_o] + [M_{ao}G_o]^T + [G^T_o]\,[M_{oo}][G_o]$$

136. Go to DMAP No. 138 if no viscous damping matrix.

137. SMP2 partitions constrained viscous damping matrix

$$[B_{ff}] = \left[\begin{array}{c|c} B_{aa} & B_{ao} \\ \hline B_{oa} & B_{oo} \end{array}\right]$$

and performs reduction

$$[B^1_{aa}] = [B_{aa}] + [B_{ao}][G_o] + [B_{ao}G_o]^T + [G_o^T][B_{oo}][G_o]$$

139. Go to DMAP No. 141 if no structural damping matrix.

140 SMP2 partitions constrained structural damping matrix

$$[K^4_{ff}] = \left[\begin{array}{c|c} K^4_{aa} & K^4_{ao} \\ \hline K^4_{oa} & K^4_{oo} \end{array}\right]$$

and performs matrix reduction

$$[K^4_{aa}] = [K^4_{aa}] + [K^4_{ao}][G_o] + [K^4_{ao}G_o]^T + [G_o^T][K^4_{oo}][G_o]$$

142. Equivalence $[G_o]$ to $[G^d_o]$ and $[G_m]$ to $[G^d_m]$ if no extra points introduced for dynamic analysis.

145. BMG generates DMIG card images describing the interconnection of the fluid and the structure.

148. Go to DMAP No. 150 if no fluid structure interface is defined.

149. MTRXIN generates fluid boundary matrices $[A_{b,f\ell}]$ and $[K_{b,f\ell}]$ if a fluid structure interface is defined. The matrix $[K_{b,f\ell}]$ is generated only for a nonzero gravity in the fluid.

151. Go to next DMAP instruction if cold start or modified restart. LBL13 will be altered by the Executive System to the proper location inside the loop for unmodified starts within the loop.

152. Beginning of loop for additional sets of direct input matrices.

154. CASE extracts user requests from CASECC for current loop.

155. MTRXIN selects the direct input matrices for the current loop, $[K^{2d}_{pp}]$, $[M^{2d}_{pp}]$ and $[B^2_{pp}]$.

158. Equivalence $[M^{2d}_{pp}]$ to $[M^2_{pp}]$ if no $[A_{b,f\ell}]$.

159. ADD5 adds $[K_{b,f\ell}]$ and $[K^{2d}_{pp}]$ and subtracts $[A_{b,f\ell}]$ from them to form $[K^2_{pp}]$.

160. Go to DMAP No. 163 if no $[A_{b,f\ell}]$.

161. Transpose $[A_{b,f\ell}]$ to obtain $[A_{b,f\ell}]^T$.

162. ADD assembles input matrix $[M^2_{pp}]$ = MFACT $[A_{b,f\ell}]^T + [M^{2d}_{pp}]$.

169. Go to DMAP No. 172 if transient type GKAD matrices are to be generated.

170. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints applied, $[M_{aa}]$ to $[M_{dd}]$ if no direct input mass matrices and no extra points and $[B_{aa}]$ to $[B_{dd}]$ if no direct input damping matrices and no extra points.

172. Go to DMAP No. 175.

173. Equivalence $[M^2_{pp}]$ to $[M^2_{dd}]$, $[B^2_{pp}]$ to $[B^2_{dd}]$ and $[K^2_{pp}]$ to $[K^2_{dd}]$ if no constraints applied, $[M_{aa}]$ to $[M_{dd}]$ if no direct input mass matrices and no extra points, and $[K_{aa}]$ to $[K_{dd}]$ if no direct input stiffness matrices and no extra points.

176. Go to DMAP No. 178 if only extra points are defined.

177. GKAD assembles stiffness, mass, and damping matrices for use in Direct Frequency Response, <u>if parameter GKAD = FREQRESP.</u>

$$[K_{dd}] = (1 + ig)[K^1_{dd}] + [K^2_{dd}] + i[K^4_{dd}] ,$$
$$[M_{dd}] = [M^1_{dd}] + [M^2_{dd}] \text{ and}$$
$$[B_{dd}] = [B^1_{dd}] + [B^2_{dd}] .$$

Direct input matrices may be complex.

or

GKAD assembles stiffness, mass, and damping matrices for use in Direct Transient Response <u>if parameter GKAD = TRANRESP.</u>

$$[K_{dd}] = [K^1_{dd}] + [K^2_{dd}] ,$$
$$[M_{dd}] = [M^1_{dd}] + [M^2_{dd}] ,$$
and
$$[B_{dd}] = [B^1_{dd}] + [B^2_{dd}] + \frac{g}{\omega_3}[K^1_{dd}] + \frac{1}{\omega_4}[K^4_{dd}] ,$$

where

$$\left[\begin{array}{c|c} K_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] \Rightarrow [K^1_{dd}] ,$$

$$\left[\begin{array}{c|c} M_{aa} & 0 \\ \hline 0 & 0 \end{array}\right] \Rightarrow [M^1_{dd}] ,$$

$$\begin{bmatrix} B_{aa} & | & 0 \\ \hline 0 & | & 0 \end{bmatrix} \Rightarrow [B^1_{dd}] ,$$

and

$$\begin{bmatrix} K^4_{aa} & | & 0 \\ \hline 0 & | & 0 \end{bmatrix} \Rightarrow [K^4_{dd}] .$$

All matrices are real.

179. Go to DMAP No. 182 if transient type GKAD matrices were generated.

180. Equivalence $[K^2_{dd}]$ to $[K_{dd}]$ if all stiffness is Direct Matrix Input, $[M^2_{dd}]$ to $[M_{dd}]$ if all mass is Direct Matrix Input and $[B^2_{dd}]$ to $[B_{dd}]$ if all damping is Direct Matrix Input.

181. Go to DMAP No. 184.

183. Equivalence $[B^2_{dd}]$ to $[B_{dd}]$ if all damping is Direct Matrix Input, $[M^2_{dd}]$ to $[M_{dd}]$ if all mass is Direct Matrix Input and $[K^2_{dd}]$ to $[K_{dd}]$ is all stiffness is Direct Matrix Input.

185. Go to DMAP No. 208 if loading is frequency-dependent.

189. Beginning of loop for additional subcases for time-dependent loads.

190. CASE extracts user requests from CASECC for th current loop.

193. TRLG generates matrices of loads versus time. $\{P1^t_d\}$ is generated with one column per output time step. $\{P1_d\}$ is generated with one column per solution time step, and the Transient Output List (TOL) is a list of output time steps.

194. SDR1 appends $\{P1^t_d\}$ to $\{P^t_d\}$.

195. SDR1 appends $\{P1_d\}$ to $\{P_d\}$.

197. Go to DMAP No. 200 if no additional time-dependent loads need to be processed.

198. Go to DMAP No. 189 if additional time-dependent loads need to be processed.

199. Go to DMAP No. 360 and print message if more then 100 loops.

202. Equivalence $\{P_d\}$ to $\{P^t_d\}$ if the output times are the same as the solution times.

204. DUMMOD2 generates a Frequency Response List (FRLZ), and a Frequency Output List (FOL), from the Transient Output List (TOL). Load reordering matrices REORDER1 and REORDER2 are generated based on parameter values. This module, in effect, generates data blocks necessary to convert time-dependent loads into frequency dependent loads.

205. Equivalence FRLZ to FRL and FOLZ to FOL.

207. Go to DMAP No. 234.

209. FRLG forms the dynamic load vectors $\{P_p^f\}$, $\{P_s^f\}$, $\{P_d^f\}$ and Frequency Output List (FOL) for frequency-dependent loads.

210. Go to DMAP No. 213 if FRLX was not generated by DUMMOD1.

211. MPYAD uses PDZERO from DUMMOD1 to zero out selected columns of $\{P_p^f\}$ in base acceleration problems.

212. Equivalence $\{PX_p^f\}$ to $\{P_p^f\}$.

214. Go to DMAP No. 222 if not a base acceleration problem.

215. MPYAD forms the complete base acceleration matrix, $\{M2BASEXG_g^f\} = [M2GG_{gg}] \cdot \{BASEXG_g^f\}$.

216. ADD assembles the frequency dependent loads and the loads due to base acceleration.

$$\{P1^f_p\} = \{P^f_p\} - \{M2BASEXG^f_g\}$$

<u>Note</u> that the p-set and g-set are the same because no extra points are allowed.

217. Equivalence $\{P1^f_p\}$ to $\{P^f_p\}$.

218. Go to DMAP No. 221 if there are no SPC's, MPC's or OMITS.

219. SSG2 applies constraints to $\{P^f_p\}$.

228. Go to DMAP No. 268 if parameter CYCIO = -1.

230. CYCT1 transforms loads on analyses points to symmetric components.

231. Go to DMAP No. 365 and print error message if a CYCT1 error was found.

233. Go to DMAP No. 268.

236. Go to DMAP No. 251 if parameter CYCIO = +1.

237. Equivalence $\{P^t_d\}$ and {PDTRZ1} if REORDER1 was not generated by DUMMOD2.

238. Go to DMAP No. 240 if REORDER1 was not generated.

239. MPYAD reorders columns of $\{P^t_d\}$.

241. CYCT1 transforms loads on analysis points to symmetric components, in time.

242. Go to DMAP No. 365 and print error message if a CYCT1 error was found.

244. Equivalence {PXTRZ1} and {PXFZ1} if REORDER2 was not generated by DUMMOD2.

246. MPYAD reorders columns of {PXTRZ1}.

248. Equivalence {PXFZ1} to {PXF1}.

250 Go to DMAP No. 264.

252. MPYAD reorders columns of $\{P^t_d\}$.

253. CYCT1 transforms loads on analysis points to summetric components, in time.

254. Go to DMAP No. 365 and print error message if a CYCT1 error was found.

256. Equivalence {PXTRZ2} to {PXTR2} if REORDER2 was not generated.

257. Go to DMAP No. 259 if REORDER2 was not generated.

258. MPYAD reorders columns of {PXTRZ2}.

260. CYCT1 transform symmetric components, in time, to summetric components.

261. Go to DMAP No. 365 and print error message if a CYCT1 error was found.

262. Equivalence {PXFZ2} to {PXF1}.

265. COPY makes a physical copy of {PXF1} called {PFX2}.

266. ADD makes loads complex, since SDR2 expects complex loads in a frequency response problem. Time-dependent loads are real.

$$\{PFX\} = (0.5, 1.0_i) \cdot \{PFX1\} + (0.5, -1.0_i) \cdot \{PFX2\}$$

271. Go to DMAP No. 282 if KMIN = 0.

274. Beginning of loop to create KMIN null columns of $\{UV_x^f\}$ for KINDEX = 0 to (KMIN-1). These leading null columns are necessary because CYCT1 expects columns for KINDEX = 0 to KMAX.

275. CYCT2 transforms loads from symmetric components to solution set for rotational symmetry. This operation is necessary to get a correct size matrix for generating null $\{UV_x^f\}$ columns.

276. Go to DMAP No. 365 and print error message if a CYCT2 error was found.

277. ADD generates a null vector $\{UVZ_1^f\} = \{PZ_k^f\}* 0.0$.

278. CYCT2 finds symmetric components of displacements from solution set data and appends it to $\{UV_x^f\}$.

279. Go to DMAP No. 365 and print error message if a CYCT2 error was found.

280. PARAM increments the value of KMINV=KMINV+1.

281. Go to DMAP No. 274 if more null vectors are to be generated for $\{UV_x^f\}$. If the initial $\{UV_x^f\}$ for KINDEX values 0 to (KMIN-1) has been completed then go to DMAP No. 282.

284. Beginning of loop for cyclic index value (KINDEX), for values KINDEX = KMIN to KMAX.

288. CYCT2 transforms stiffness and mass matrix from symmetric components to solution set for rotational symmetry by the equation:

$$[K_{kk}] = [G_c^T][K_{aa}][G_c] + [G_s^T][K_{aa}][G_s]$$

291. CYCT2 transforms damping and loads from symmetric components to solution set for rotational symmetry by the equations:

$$[B_{kk}] = [G_c^T][B_{aa}][G_c] + [G_s^T][B_{aa}][G_s]$$

$$[P_k] = [G_c^T]\{P_c\} + [G_s^T]\{P_s\}$$

294. Go to DMAP No. 365 and print error message if CYCT2 error was found.

296. FRRD2 solves for the displacements using the following equation:

$$[-M_{dd}w^2 + iB_{dd}w + K_{dd}]\{U_d\} = \{P_d\}.$$

298. CYCT2 finds symmetric components of displacement from solution set data and appends to output for each KINDEX.

299. Go to DMAP No. 365 and print error message if CYCT2 error was found.

301. PARAM increments the value of KINDEX = KINDEX + 1.

303. Go to DMAP No. 306 if all cyclic index values are complete.

304. Go to DMAP No. 284 if additional index values are needed.

305. Go to DMAP No. 360 and print error message if more than 100 loops on KINDEX.

307. Equivalence $\{U_x^f\}$ to $\{U_d^f\}$ if parameter CYCIO = -1.

309. Go to DMAP No. 312 if parameter CYCIO = -1.

310. CYCT1 transforms displacements from symmetrical components to physical components.

313. Go to DMAP No. 322 if loads were frequency-dependent.

314. Equivalence $\{P_x^f\}$ to $\{PZ_d^f\}$ if parameter CYCIO = -1.
315. Go to DMAP No. 317 if parameter CYCIO = -1.
316. CYCT1 transforms loads from symmetrical components to physical components if loads were time-dependent.

318. SDR1 recovers dependent loads $\{PZ_p^f\}$.

319. SSG2 applies constraints to $\{PZ_p^f\}$ to form $\{PZ_s^f\}$.

320. Equivalence $\{PZ_p^f\}$ to $\{P_p^f\}$ and $\{PZ_s^f\}$ to $\{P_s^f\}$.

323. VDR prepares displacements, sorted by frequency, for output using only the independent degrees of freedom.

324. Go to DMAP No. 333 if no output request for the independent degrees of freedom.

325. Go to DMAP No. 331 if no output request for independent displacements sorted by point number.

326. SDR3 sorts the independent displacements by point number.

327. ØFP formats the requested independent displacements, sorted by point number, prepared by SDR3 and places them on the system output file for printing.

328. XYTRAN prepares the input for X-Y plotting of the independent displacements vs. frequency.

329. XYPLØT prepares the requested X-Y plots of the independent displacements vs. frequency.

332. ØFP formats the requested independent displacements, sorted by frequency, prepared by VDR and places them on the system output file for printing.

334. Go to DMAP No. 357 if no [illegible] involving dependent degrees of freedom for forces and stresses.

335. Equivalence $\{u_d\}$ to $\{u_p\}$ if no constraints applied.

336. Go to DMAP No. 338 if no constraints applied.

337. SDR1 recovers independent components of displacements

$$\{u_o\} = [G_o^d]\{u_d\} \quad , \qquad \begin{Bmatrix} u_d \\ \hline u_o \end{Bmatrix} = \{u_f + u_e\} \quad ,$$

$$\begin{Bmatrix} u_f + u_e \\ \hline u_s \end{Bmatrix} = \{u_n + u_e\} \quad , \qquad \{u_m\} = [G_m^d]\{u_f + u_e\} \quad ,$$

$$\begin{Bmatrix} u_n + u_e \\ \hline u_m \end{Bmatrix} = \{u_p\}$$

and recovers single-point forces of constraing $\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\}$.

339. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares load vectors (ØPPC1), displacement vectors (ØUPVC1), and single-point forces of constraint (ØQPC1) for output sorted by frequency.

340. Go to DMAP No. 351 if no output requests sorted by point number of element number.

341. SDR3 prepares requested output sorted by point number or element number.

342. ØFP formats tables prepared by SDR3, sorted by point number or element number, and places them on the system output file for printing.

343. XYTRAN prepares the input for requested X-Y plots.

344. XYPLØT prepares the requested X-Y plots of displacements, forces, stresses, loads or single-point forces of constraint vs. frequency.

345. Go to DMAP No. 353 if no Power Spectral Density List

346. RANDOM calculates power spectral density functions (PSDF) and autocorrelation functions (AUTØ) using the previously calculated frequency response.

347. Go to DMAP No. 353 if no RANDØM calculations requested.

348. XYTRAN prepares the input for requested X-Y plots of the RANDØM output.

349. XYPLØT prepares the requested X-Y plots of autocorrelation functions and power spectral density functions.

350. Go to DMAP No. 353 if no frequency response output requests sorted by frequency.

352. ØFP formats frequency response output requests prepared by SDR2, sorted by frequency, and places them on the systm output file for printing.

354. Go to DMAP No. 357 if no deformed structure plots are requested.

355. PLOT generates all requested deformed plots.

356. PRTMSG prints plotter data and engineering data for each deformed plot generated.

358. Go to DMAP No. 383 if no additional sets of direct input matrices need to be processed.

359. Go to DMAP No. 152 if additional sets of direct input matrices need to be processed.

361. DIRECT FREQUENCY AND RAMDØM RESPØNSE ERRØR MESSAGE NO. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

364. DIRECT FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 4 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

366. STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 7 - CYCLIC SYMMETRY DATA ERRØR.

368. Coupled mass is not allowed - Print parameter COUPMASS.

371. STATICS WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 6 - FREE-BØDY SUPPØRTS NØT ALLØWED.

373. EPoint bulk data not allowed - Print parameter NOUE.

376. Neither FREQ or TSTEP were in bulk data - Print parameters NOFRL and NOTRL.

380. Both FREQ and TSTEP were selected in case control - Print parameters NOFREQ and NOTIME.

384. END of DMAP sequence.

2.4.4 CASE CONTROL DECK AND PARAMETERS FOR FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES

The following items relate to subcase definition and data selection for Forced Vibration and Random Response of Rotating Cyclic Structures:

1. The SPC and MPC request must appear above the subcase level and may not be changed.
2. Either FREQUENCY or TSTEP must be selected and must be above the subcase level.
3. If selected, FREQUENCY must be used to select one and only one FREQ, FREQ1 or FREQ2 card from the Bulk Data deck.
4. If selected, TSTEP must be used to select the time-steps to be used for load definition via a TSTEP Bulk Data card and must be defined above the subcase level.
5. Direct input matrices are not allowed.
6. OFREQ must not be used.
7. A separate group of subcases must be defined for each symmetric segment.
8. DLOAD must be used to define a frequency or time-dependent loading condition for each subcase. For frequency-dependent loads, subcases without loads need not refer to a DLOAD card. For time-dependent loads, subcases without loads must refer to a DLOAD card that explicitly generates a null load.
9. An alternate loading method is to define a separate group of subcases for each harmonic index, k. The parameter CYCIØ is included and the load components for each index are defined directly within each group for the various loading conditions.
10. If Random Response calculations are desired, RANDOM must be used to select RANDPS and RANDTi cards from the Bulk Data Deck.

The following printed output, sorted by freqeuncy (SØRT1) or by point number or element number (SØRT2), is available, either as real and imaginary parts or magnitude and phase angle (0° - 360° lead), for the list of fequencies specified:

1. Displacements, velocities, and accelerations for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SØLUTIØN points (points used in formulation of the general K system).
2. Nonzero components of the applied load vector and single-point forces of constraint for a list of PHYSICAL points.
3. Stresses and forces in selected elements (ALL available only for SORT1).

The following plotter output is available for Frequency Response calculations:

1. Undeformed plot of the structural model.

2. X-Y plot of any component of displacement, velocity, or acceleration of a PHYSICAL point or SØLUTIØN point.

3. X-Y plot of any component of the applied load vector or single-point force of constraint.

4. X-Y plot of any stress or force component for an element.

The following plotter output is available for Random Response calculations:

1. X-Y plot of the power spectral density versus frequency for the response of selected components for points or elements.

2. X-Y plot of the autocorrelation versus time lag for the response of selected components for points or elements.

The data used for preparing X-Y plots may be punched or printed in tabular form (see Section 4.3). This is the only form of printed output that is available for Random Response. Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

The following items relate to Bulk Data restrictions:

1. SUPORT cards are not allowed.

2. EPOINT cards are not allowed.

3. SPOINT cards are not allowed.

4. CYJOIN cards <u>are</u> required.

5. If a TSTEP card is used then it must not be continued since only one uniform time step interval must be specified. The skip factor for output, NO, on the TSTEP card must be 1.

The following parameters are used in Forced Vibration and Random Response of Rotating Cyclic Structures:

1. <u>GRDPNT</u> - optional - A positive integer value of this parameter will cause the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.

2. <u>WTMASS</u> - optional - The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in EMA. Not recommended for use in hydroelastic problems.

3. <u>COUPMASS</u> - fixed - Only lumped mass matrices must be used.

4. GKAD - optional - The BCD value of this parameter is used to tell the GKAD module the desired form of matrices KDD, BDD and MDD. The BCD value can be FREQRESP or TRANRESP. The default is TRANRESP.
NOTE: Remember to define parameters G, W3 and W4. See Section 9.3.3 (DIRECT DYNAMIC MATRIX ASSEMBLY) Pages 9.3-7 and 9.3-8 of the NASTRAN theoretical manual for further details.

5. LGKAD - optional - The integer value of this parameter is used in conjunction with parameter GKAD. If GKAD = FREQRESP then set LGKAD = 1, if GKAD = TRANRESP set LGKAD = -1. The default value is -1.

6. G - optional - The real value of this parameter is used as a uniform structural damping coefficient in the direct formulation of dynamics problems. Not recommended foruse in hydroelastic problems (use GE on MAT1).

7. W3 - optional - The real value of this parameter is used as a pivotal frequency for uniform structural damping if parameter GKAD = TRANRESP. In this case W3 is required if uniform structural damping is desired. The default value is 0.0.

8. W4 - optional - The real value of this parameter is used as a pivotal frequency for element structural damping if parameter GKAD = TRANRESP. In this case W4 is required if structural damping is desired for any of the structural elements. The default value is 0.0.

9. NSEGS - required - The integer value of this parameter is the number of identical segments in the structural model.

10. CYCIØ - required - The integer value of this parameter specifies the form of the input and output data. A value of +1 is used to specify physical segment representation, and a value of -1 for cyclic transform representation. There is no default.

11. CYCSEQ - fixed - The integer value of this parameter specifies the procedure for sequencing the equations in the solution set. A value of +1 specifies that all cosine terms should be sequenced before all sine terms, and a value of -1 for alternating the cosine and sine terms. The value of CYCSEQ has been set to -1.

12. CTYPE - fixed - The BCD value of this parameter defines the type of cyclic summetry as follows:

    (1) RØT - rotational symmetry

13. KMAX - required - The integer value of this parameter specifies the maximum value of the harmonic index. There is no default for this parameter. The maximum value that can be specified is NSEGS/2.

14. KMIN - optional - The integer value of this parameter specifies the minimum value of the harmonic index to be used in the solution loop. KMIN can equal KMAX. The default is 0.

15. NLØAD - fixed - The integer value of this parameter is the number of static loading conditions. The value of NLOAD is internally computed.

16. NOKPRT - optional - An integer value of +1 for this parameter will cause the current harmonic index, KINDEX, to be printed at the top of the harmonic loop. The default is +1.

17. LMAX - optional - The integer value of this parameter specifies the maximum harmonic in the fourier decomposition of periodic, time-dependent loads. The default value is NTSTEPS/2, where NTSTEPS = N+2 where N is from the TSTEP bulk data card.

18. RPS - optional - The real value of this parameter defines the rotational speed of the structure in revolutions per unit time. The default is 0.0.

19. BXTID, BYTID, BZTID, BXPTID, BYPTID, BZPTID - optional - The positive integer values of these parameters define the set identification numbers of the TABLEDi bulk data cards which define the components of the base acceleration vector. The tables referred to by BXTID, BYTID and BZTID define magnitude (LT-2) and tables referred to by BXPTID, BYPTID and BZPTID define phase (degrees). The default values are -1, which means that the respective terms will be ignored.

3. PROGRAMMER'S MANUAL

3.1 DATA BLOCK AND TABLE DESCRIPTION

3.1.1 Data Blocks Output from Module DUMMOD1

3.1.1.1 FRLX (TABLE)

Description

Frequency Response List

The FRLX contains one logical record for each different set defined in the bulk data. Each record contains a sorted list of frequencies defined in the set.

Table Format

Record	Word	Type	Item
0	1, 2	BCD	Data block name
	3	I	Set ID_1
	⋮		
	2+n	I	Set ID_n
1	1-m	R	Radian frequencies belonging to set ID_1 ($w = 2\pi F$)
⋮			⋮
n	1-k	R	Radian frequencies belonging to set ID_n ($w = 2\pi F$)
n+1			End-of-file

Table Trailer

Word 1 = number of frequency sets

Word 2-6 = zero

3.1.1.2 B1GG (MATRIX)

Description

$[B1GG_{gg}]$ = Coriolis acceleration coefficient matrix - g set.

3.1.1.3 M1GG (MATRIX)

Description

$[M1GG_{gg}]$ - Centripetal acceleration coefficient matrix - g set.

3.1.1.4 M2GG (MATRIX)

Description

$[M2GG_{gg}]$ - Base acceleration coefficient matrix - g set.

3.1.1.5 BASEXG (MATRIX)

Description

$[BASEXG_g^F]$ - Base acceleration matrix - g set.

3.1.1.6 PDZERO (MATRIX)

Description

$[PDZERO_g^F]$ - Load modification matrix in base acceleration problems - g set.

3.1.2 Data Blocks Output from Module DUMMOD2

3.1.2.1 FRL (TABLE)

Description

Frequency Response List

The FRL output by DUMMOD2 contains one logical record. This logical record contains a sorted list of frequencies.

Table Format

Record	Word	Type	Item
0	1,2	BCD	Data Block Name
	3	I	Set ID = 1
1	1-m	R	Radian frequencies ($w = 2\pi F$)
2			End-of-file

Table Trailer

Word 1 = 1
Word 2-6 = zero

3.1.2.2 FOL (TABLE)

Description

Frequency Response Output List

Table Format

Record	Word	Type	Item
0	1-2	BCD	Table Name
	3-NFREQ+2	R	Frequencies F ($w = 2\pi F$)
1			End-of-file

Table Trailer

Word 1 = Number of frequencies (NFREQ)
Word 2 = Frequency set record number (=1)
Word 3-6 = zero

3.1.2.3 REORDER1 (MATRIX)

Description

[REORDER1] - Load reordering matrix in time-dependent frequency response problems for cyclic structures.

Matrix Trailer

Number of columns =	NTSTEPS*FKMAX, if CYCIO = -1
Number of rows =	NTSTEPS*NSEGS, if CYCIO = +1
Form	= square
Type	= real singer precision

3.1.2.4 REORDER2 (MATRIX)

Description

[REORDER2] - Load reordering matrix in time-dependent frequency response problems for cyclic structures.

Matrix Trailer

Number of columns =	FLMAX*FKMAX, if CYCIO = -1
Number of rows =	FLMAX*NSEGS, if CYCIO = +1
Form	= square
Type	= real single precision

3.2 FUNCTIONAL MODULES

3.2.1 Functional Module DUMMOD1

3.2.1.1 Entry Point: DUMOD1

3.2.1.2 Purpose

To generate the Coriolis, centripetal and base acceleration coefficient matrices and the base acceleration matrix for a forced vibration response analysis of rotating structures.

3.2.1.3 DMAP Calling Sequence

```
DUMMOD1 CASECC, BGPDT, CSTM, DIT, FRL, MGG,,/FRLX, B1GG, M1GG, M2GG,
        BASEXG, PDZERO,,/V, N, NOMGG/V, Y, CYCIO/V, Y, NSEGS/V, Y,
        KMAX/V, N, FKMAX/V, Y, BXTID=-1/V, Y, BXPTID=-1/V, Y, BYTID=-1/
        V, Y, BYTID=-1/V, Y, BYPTID=-1/V, Y, BZTID=-1/V, Y, BZPTID=-1/
        V, N, NOBASEX/V, N, NOFREQ/V, N, OMEGA $
```

3.2.1.4 Input Data Blocks

CASECC - Case Control.
BGPDT - Basic Grid Point Definition Table.
CSTM - Coordinate System Transformation Matrices.
DIT - Direct Input Tables
FRL - Frequency Response List (radians).
MGG - Partition of mass matrix (g-set).

Notes: 1. All input data blocks can be purged if only parameters FKMAX and NOBASEX are to be computed.
2. CASECC, DIT and FRL can be purged if output data blocks FRLX and BASEXG are purged.

3.2.1.5 Output Data Blocks

FRLX - Frequency Response List (modified)
B1GG - Coriolis acceleration coefficient matrix (g-set)
M1GG - Centripetal acceleration coefficient matrix (g-set)
M2GG - Base Acceleration coefficient matrix (g-set)
BASEXG - Base acceleration matrix (g-set x f)
PDZERO - Load modification matrix in base acceleration problems (g-set x f)

Notes: 1. All output data blocks can be purged if parameter NOMGG=-1.
2. B1GG and M1GG can be purged if NOMGG=-1 or if OMEGA=0.0.

3. FRLX and PDZERO can be purged if OMEGA=0.0.
4. FRLX, PDZERO, M2GG and BASEXG can be purged if NOMGG=-1 or if NOFREQ=-1 or if CYCIO=+1 or if all three parameters BXTID=BYTID=BZTID=-1.

3.2.1.6 Parameters

NOMGG - Input-integer-no default. MGG was not generated if NOMGG=-1.

CYCIO - Input-integer-no default. This parameter specifies the form of the input and output data from cyclic structures. A value of +1 is used to specify physical segment representation and a value of -1 for cyclic transformation representation.

NSEGS - Input-integer-no default. The number of identical segments in the structural model.

KMAX - Input-integer-no default. KMAX specifies the maximum value of the harmonic index. The maximum value that can be specified for KMAX is NSEGS/2.

FKMAX - Output-integer-no default. FKMAX is a function of KMAX.

NOBASEX - Output-integer-no default. NOBASEX=-1 if data block BASEXG is not generated.

NOFREQ - Input-integer-no default. NOFREQ=-1 if FREQUENCY was not selected in the Case Control deck.

OMEGA - Input-real-no default. Rotational speed of the structure in radians. OMEGA = $2\pi \cdot$RPS.

BXTID
BYTID
BZTID
BXPTID
BYPTID
BZPTID - Input-integer-defaults. The values of these parameters define the set identification numbers of the TABLEDi Bulk Data cards which define the components of the base acceleration vector. The tables referred to by BXTID, BYTID and BZTID define magnitude (LT-2) and the tables referred to by BXPTID, BYPTID and BZPTID define phase (degrees). The default values are -1 which means that the respective terms are ignored.

3.2.1.7 Method

Parameters NOBASEX and FKMAX are computed depending on the values of various input parameters. Parameter NOBASEX is set equal to -1 if parameters NOMGG=-1 or CYCIO=+1 or NOFREQ=-1 or if parameters BXTID=BYTID=BZTID=-1, otherwise NOBASEX is set equal to +1 indicating that base acceleration data blocks are to be generated.

If parameter CYCIO=-1, then parameter FKMAX is computed as follows. If NSEGS is odd then FKMAX=2*KMAX+1. If NSEGS is even and KMAX=NSEGS/2, then FKMAX=NSEGS, otherwise FKMAX=2*KMAX+1.

If parameter NOMGG=-1 then no data blocks are generated and an exit is made from module DUMMOD1, otherwise computations proceed in three phases. In the first phase B1GG and M1GG are generated unless parameter OMEGA=0.0. M2GG is generated if parameter NOBASEX=+1. The second and third phases generate data blocks associated with base acceleration problems and are only executed if NOBASEX=+1. In the second phase FRLX and PDZERO are generated unless parameter OMEGA=0.0. Data block BASEXG is generated and output in phase three.

3.2.1.7.1 Phase 1 - Generation of B1GG, M1GG and M2GG

Phase one begins with a request for open core and buffer allocation. If OMEGA=0.0 then B1GG anf M1GG are not output and their buffers, IBUF3 and IBUF4, are not allocated and IBUF5 is set equal to IBUF3. If coordinate system transformations exist then the CSTM data block is open and the coordinate system information is placed in core and readied for use by subroutine PRETRD.

The primary loop in phase one is controlled by the number of grid points in the Basic Grid Point Definition Table (BGPDT), scalar points are not allowed by DUMMOD1. Each grid point in the BGPDT is considered in order and the corresponding columns of the mass matrix, MGG, are processed to form B1GG, M1GG and M2GG. When all grid points have been processed the necessary trailers are written. For the i^{th} grid point in the BGPDT the corresponding translational terms of MGG are unpacked and the diagonal terms are isolated into a 3 x 3 matrix $[M_i^1]$. If the grid point is not in the basic system then subroutine TRANSD calculates the 3 x 3 transformation matrix $[T_i]$ from global coordinates to basic coordinates for the grid point and $[M_i^1]$ is transformed to the basic system to form $[\overline{M}_i]$. The average of the three diagonal terms of $[\overline{M}_i]$ is then used to form $[\overline{BT}_i]$, $[\overline{MT}_i]$ and $[\overline{M2}_i]$. These three submatrices are then transformed back to the global coordinate system, if necessary. The 3 x 3 matrices $[\overline{BT}_i]$, $[\overline{MT}_i]$ and $[\overline{M2}_i]$ are then packed into the B1GG, M1GG and M2GG matrices.

(a)

$$[MGG]_{gxg} = \begin{bmatrix} [M_1] & & & 0 \\ & [M_2] & & \\ & & \ddots & \\ 0 & & & [M_n] \end{bmatrix}$$ where n = the total number of grid points.

where

$$[M_i]_{6\times6} = \left[\begin{array}{c|c} [M_i^1] & \\ \hline & [M_i^2] \end{array}\right] \quad \text{for } i = 1, n$$

and

$$[M_i^1]_{3\times3} = \begin{bmatrix} m_i^{T1} & 0 & 0 \\ 0 & m_i^{T2} & 0 \\ 0 & 0 & m_i^{T3} \end{bmatrix}$$

(b) Transform $[M_i^1]$ from global to basic coordinate system

$$[\overline{M}_i]_{3\times3} = [T_i]\,[M_i^1]\,[T_i]^T$$

(c) Compute average of $[\overline{M}_i]$

$$\bar{\bar{m}}_i = \frac{\sum_{k=1}^{3} \bar{m}_i^K}{3.0}$$

where $\bar{m}_i^K$ is the mass (in the basic coordinate system) at the i^{th} node point of the total of 'n' nodes in the k^{th} direction.

(d) Form B1GG

$$[B1GG]_{g\times g} = \begin{bmatrix} [B1_1] & & & 0 \\ & [B1_2] & & \\ & & \ddots & \\ 0 & & & [B1_n] \end{bmatrix}$$

where

$$[B1_i]_{6\times6} = \left[\begin{array}{c|c} [B1_i^1] & \\ \hline & [0] \end{array}\right]$$

and

$$[B1_i^1]_{3\times3} = [T_1]^T \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & -\bar{\bar{m}}_i \\ 0 & \bar{\bar{m}}_i & 0 \end{bmatrix} [T_i]$$

(e) Form M1GG

$$[M1GG]_{g\times g} = \begin{bmatrix} [M1_1] & & & 0 \\ & [M1_2] & & \\ & & \ddots & \\ 0 & & & [M1_n2] \end{bmatrix}$$

where

$$[M1_i]_{6x6} = \left[\begin{array}{c|c} [M1_i^1] & \\ \hline & [0] \end{array}\right]$$

and

$$[M1_i^1]_{3x3} = [T_i]^T \begin{bmatrix} 0 & 0 & 0 \\ 0 & \bar{\bar{m}}_i & 0 \\ 0 & 0 & \bar{\bar{m}}_i \end{bmatrix} [T_i]$$

(f) Form M2GG

$$[M2GG]_{gxg} = \begin{bmatrix} [M2_1] & & 0 \\ & [M2_2] & \\ & & \ddots & \\ 0 & & & [M2_n] \end{bmatrix}$$

where

$$[M2_i]_{6x6} = \left[\begin{array}{c|c} [M2_i^1] & \\ \hline & [0] \end{array}\right]$$

and

$$[M2_i^1]_{3x3} = [T_i]^T \begin{bmatrix} \bar{\bar{m}}_i & 0 & 0 \\ 0 & \bar{\bar{m}}_i & \bar{\bar{m}}_i \\ 0 & -\bar{\bar{m}}_i & \bar{\bar{m}}_i \end{bmatrix} [T_i]$$

3.2.1.7.2 Phase 2 - Generation of FRLX and PDZERO

In this phase the FREQUENCY set selected in the Case Control deck is located in data block FRL and stored in core. If parameter OMEGA=0.0 of if parameters BYTID=-1 and BZTID=-1 then phase two is complete, otherwise phase two processing continues. The Frequency Response List must be modified to include an expanded set of frequencies. Read and copy from FRL to FRLX record 0 and all logical records up to the selected frequency set. The only set that will be modified in FRL is the selected frequency set. Once the set of selected frequencies have been found and stored in core a vector for FRLX and PDZERO are generated using the FRL frequencies stored in core and parameter OMEGA. Let ω_i for i = 1, NFREQ be the frequencies (in radians) from FRL.

If $\omega_i \neq 0.0$, create 3 entries, 0.0, 1.0 and 0.0 for PDZERO and create 3 entries, $|\omega_i - OMEGA|$, ω_i, and $|\omega_i + OMEGA|$ for FRLX.

If ω_i = 0.0, create 2 entries, 1.0 and 0.0 for PDZERO and create 2 entries, 0.0 and |OMEGA| for FRLX.

After the expanded list of frequencies is generated call routine DUMO1E to sort it in ascending order. DUMO1E also returns a sorting index so other vectors may be sorted the same as FRLX. Sort PDZERO using this sorting index. Output this FRLX vector and continue copying the remaining records of FRL to FRLX. Output data block PDZERO by writing out the PDZERO vector FKMAX times, thus creating FKMAX columns. The original unexpanded frequencies from FRL and the sorting index stored in core are retained for phase 3 processing.

3.2.7.3 Phase 3 - Generation of BASEXG.

If NOBASEX=-1 then this phase is skipped, otherwise processing continues. A unique list of table IDs using parameters BXTID, BYTID, BZTID, BXPTID, BYPTID and BZPTID is generated and a call to PRETAB is made so that tables TABLED1, TABLED2, TABLED3 and TABLED4 can be interpolated by calls to TAB. Routines DUMO1A, DUMO1B, DUMO1C and DUMO1D are used to generate data block BASEXG. Routine DUMO1A calls the routines to generate the BASE table and outputs the BASEXG matrix. The BASE table is used to generate up to three groups of NFREQX columns, where NFREQX is the number of expanded frequencies from phase two, in the BASEXG matrix. Routine DUMO1B is called to generate the BASE table if the original FRL frequency list was not expanded, see phase two, otherwise routine DUMO1C is called. Routine DUMO1D sorts the columns of the BASE table so that they are arranged in the same order as the modified frequency set if FRLX was generated in phase two. The following is a mathematical description of matrix BASEXG.

(a) Let $\ddot{X}_o(f_i)$, $\emptyset_x(f_i)$, $\ddot{Y}_o(f_i)$, $\emptyset_y(f_i)$, $\ddot{Z}_o(f_i)$, $\emptyset_z(f_i)$ be input via frequency dependent tables TABLEDi where the table IDs are defined by parameters BXTID, BXPTID, BYTID, BYPTID, BZTID and BZPTID respectively. $\ddot{X}_o$, $\ddot{Y}_o$ and $\ddot{Z}_o$ are magnitudes in L7-2 units while $\emptyset_x$, $\emptyset_y$ and $\emptyset_z$ are phase angles in degrees.

(b) Define control flag MØDFRL.

If parameter OMEGA=0.0 or parameters BYTID=-1 and BZTID=-1 then set MODFRL to false, otherwise MODFRL is true.

(c) Let FRL be a vector of NF frequencies (in radians).

$$FRL = [\omega_1, \omega_2, \omega_3, \ldots, \omega_{NF}]$$

(d) If MODFRL is false then generate complex base table BASE of order 3 x NF.

$$[BASE]_{3xNF} = [\{Base(f_1)\}_{3x1} \cdots \{BASE(f_{NF})\}_{3x1}]$$

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where $f_i = \omega_i/2\pi$ for i = 1, 2, ..., NF
and

$$\{BASE(f_i)\}_{3x1} = \begin{Bmatrix} \ddot{X}_o(f_i) \cdot e^{i\phi_x(f_i)} \\ \ddot{Y}_o(f_i) \cdot e^{i\phi_y(f_i)} \\ \ddot{Z}_o(f_i) \cdot e^{i\phi_z(f_i)} \end{Bmatrix}_{3x1}$$

(e) If MODFRL is true then generate complex base table BASE of order 3 x NFX where NFX is an expanded number of frequencies as defined below.

$$[BASE]_{3xNFX} = \Big[[BASE(f_1)]\ [BASE(f_2)]\ .\ .\ .\ .\ [BASE(f_{NF})]\Big]$$

where $f_i = \omega_i/2\pi$ for i = 1, 2, ..., NF

and each $\{BASE(f_i)\}$ is either 3 x 2 if $\omega_i = 0.0$ or 3 x 3 if $\omega_i \neq 0.0$.

(e.1) If $\omega_i = 0.0$, then $[BASE(f_i)]_{3x2}$ is defined as follows:

$$[BASE(f_i)]_{3x2} = \begin{bmatrix} A & 0 \\ 0 & B \\ 0 & C \end{bmatrix}$$

where

SGN = 1.0 if parameter OMEGA ≥ 0.0, otherwise SGN=-1.0 and

$$A = \ddot{X}_o(f_i) \cdot e^{i\phi_x(f_i)}$$

$$B = \ddot{Y}_o(f_i) \cdot \cos(\phi_y(f_i)) - i \cdot SGN \cdot \ddot{Z}_o(f_i) \cdot \cos(\phi_z(f_i)$$

$$C = \ddot{Z}_o(f_i) \cdot \cos(\phi_z(f_i)) + i \cdot SGN \cdot \ddot{Y}_o(f_i) \cdot \cos(\phi_y(f_i))$$

(e.2) If $\omega_i \neq 0.0$, then $[BASE(f_i)]_{3x3}$ is defined as follows:

$$[BASE(f_i)]_{3x3} = \begin{bmatrix} 0 & A & 0 \\ B & 0 & C \\ D & 0 & E \end{bmatrix}$$

where

SGNA = 1.0 if $(\omega_i$ - OMEGA) ≥ 0.0, otherwise SGNA = -1.0

SGNB = 1.0 if $(\omega_i$ + OMEGA) ≥ 0.0, otherwise SGIB = -1.0

and

$$A = \ddot{X}_o(f_i) \cdot e^{i\phi_x(f_i)}$$

$$B = 0.5 \cdot \left[\ddot{Y}_o(f_i) \cdot e^{i \cdot SGNA \cdot \phi_y(f_i)} - SGNA \cdot \ddot{Z}_o(f_i) \cdot e^{i \cdot SGNA \cdot (\phi_z(f_i) - SGNA\ \frac{\pi}{2})}\right]$$

$$C = 0.5 \cdot \left[\ddot{Y}_o(f_i) \cdot e^{i \cdot SGNB \cdot \emptyset_y(f_i)} - SGNA \cdot \ddot{Z}_o(f_i) \cdot e^{i \cdot SGNB(\emptyset_z(f_i) - SGNB \cdot \pi/2)}\right]$$

$$D = 0.5 \cdot \left[SGNA \cdot \ddot{Y}_o(f_i) \cdot e^{i \cdot SGNA(\emptyset_y(f_i) - SGNA \cdot \frac{\pi}{2})} + \ddot{Z}_o(f_i) \cdot e^{i \cdot SGNA \cdot \emptyset_z(f_i)}\right]$$

$$E = 0.5 \cdot \left[-SGNB \cdot \ddot{Y}_o(f_i) \cdot e^{i \cdot SGNB(\emptyset_y(f_i) - SGNB \cdot \frac{\pi}{2})} + Z_o(f_i) \cdot e^{i \cdot SGNB \cdot \emptyset_z(f_i)}\right]$$

(f) Define the complex base acceleration matrix BASEXG of order G x (NF•FKMAX) as follows:

Let NF be the number of frequencies in the BASE matrix, i.e., let NF = NF if MODFRL was false or NF = NFX if MODFRL was true.

$$[BASEXG]_{gx(NF \cdot FKMAX)} = \left[[BASEXG^1]_{gxNF} \quad [BASEXG^2]_{gxNF} \quad [BASEXG^3]_{gxNF} \quad \ldots \quad [BASEXG^{FKMAX}]_{gxNF} \right]$$

where

$$[BASEXG^i]_{gxNF} = \begin{bmatrix} [BASEX^i]_{6xNF} \\ [BASEX^i]_{6xNF} \\ \vdots \\ [BASEX^i]_{6xNF} \end{bmatrix} \qquad \text{for } i = 1, 2 \text{ and } 3$$

and

$$[BASEXG^i]_{gxNF} = [0] \text{ for } i = 4,5,6,\ldots, FKMAX$$

NOTE: $[BASEX^i]$ is repeated N times where N = g/6 and g is the g-set size. Scalar points are not allowed so each node has 6 degrees of freedom.

$$[BASEX^1]_{6xNF} = \begin{bmatrix} BASE(1,1) & BASE(1,2) & \ldots & BASE(1,NF) \\ 0 & 0 & & 0 \\ 0 & 0 & & 0 \\ 0 & 0 & & 0 \\ 0 & 0 & & 0 \\ 0 & 0 & & 0 \end{bmatrix}$$

$$[BASEX^2]_{6xNF} = \begin{bmatrix} 0 & 0 & \cdots & 0 \\ BASE(2,1) & BASE(2,2) & & BASE(2,NF) \\ BASE(3,1) & BASE(3,2) & & BASE(3,NF) \\ 0 & 0 & & 0 \\ 0 & 0 & & 0 \\ 0 & 0 & & 0 \end{bmatrix}$$

$$[BASEX^3]_{6xNF} = \begin{bmatrix} 0 & 0 & \cdots & 0 \\ BASE(3,1) & BASE(3,2) & & BASE(3,NF) \\ -BASE(2,1) & -BASE(2,2) & & -BASE(2,NF) \\ 0 & 0 & & 0 \\ 0 & 0 & & 0 \\ 0 & 0 & & 0 \end{bmatrix}$$

3.2.1.8 Subroutines

Utility subroutines GMMATD, PRETRD, TRANSD, PRETAB and TAB are used. See subroutine descriptions, Section 3 of NASTRAN Programmer's Manual.

3.2.1.8.1 Subroutine Name: DUMO1A

1. Entry Point: DUMODIA

2. Purpose: To define and output the complex single precision base acceleration matrix BASEXG.

3. Calling Sequence: Call DUMO1A (BASE, BASE1, Z, W, BUF, INDEX, MODFRL, BASEXG, NROW, NF, NFX, FKMAX, OMEGA)

BASE - Storage for BASE matrix - complex S.P. - input.
BASE1 - Storage for sorted BASE matrix - complex S.P. - input.
Z - Storage for one column of matrix BASEXG - complex S.P. - input.
W - Frequencies (radians) from data block FRL - real - input.
BUF - GINO buffer for BASEXG - real - input
INDEX - Sorting index - integer - input
MODFRL - Flag to indicate if frequency list was expanded - logical - input.
BASEXG - GINO file number of BASEXG - integer - input.
NROW - G-set size - integer - input.
NF - Number of frequencies in FRL data block - integer - input.
NFX - Expanded number of frequencies - integer - input.
FKMAX - Function of parameter KMAX - integer - input.
OMEGA - Rotational speed of structure in radians - real - input.

3.2.1.8.2 Subroutine Name: DUM01B

1. Entry Point: DUM01B

2. Purpose: To define the complex single precision BASE matrix used in generating the complete base acceleration matrix BASEXG. This routine is only called if MODFRL is false.

3. Calling Sequence: CALL DUM01B (BASE, W, NF)

   BASE - BASE matrix - complex S.P. - output
   W - Frequencies from data block FRL - real (radians) - input.
   NF - Number of frequencies in W - integer - input.

   COMMON/CONDAS/PI, TWOPI, RADEG, DEGRA, S4PISQ
   COMMON/BLANK/DUM(5), BXTID, BXPTID, BYTID, BYPTID, BZTID, BZPTID

3.2.1.8.3 Subroutine Name: DUM01C

1. Entry Point: DUM01C

2. Purpose: To define the complex single precision BASE matrix used in generating the complete base acceleration matrix BASEXG. This routine is only called if MODFRL is true.

3. Calling Sequence: CALL DUM01C (BASE, W, OMEGA, NF)

   BASE - BASE matrix - complex S.P. - output.
   W - Frequencies from data block FRL - real (radians) - input.
   OMEGA - Rotational speed of the structure in radians - real - input.
   NF - Number of frequencies in W - integer - input.

   COMMON/CONDAS/PI, TWOPI, RADEG, DEGRA, S4PISQ
   COMMON/BLANK/DUM(5), BXTID, BXPTID, BYTID, BYPTID, BZTID, BZPTID

3.2.1.8.4 Subroutine Name: DUM01D

1. Entry Point: DUM01D

2. Purpose: To sort the columns of matrix BASE in the same order as the expanded frequencies in data block FRLX.

3. Calling Sequence: CALL DUM01D (BASE, BASE1, INDEX, NFX)

   BASE - BASE matrix - complex S.P. - input/output
   BASE1 - Temporary storage used for sorting matrix BASE - complex S.P. - input.
   INDEX - Sorting key - integer - input

NFX - Number of columns of matrix BASE and length of INDEX - integer - input.

3.2.1.8.5 Subroutine Name: DUMO1E

1. Entry Point: DUMO1E

2. Purpose: To sort the list of expanded frequencies of data block FRLX and to supply an index key so these vectors can be sorted the same way.

3. Calling Sequence: CALL DUMO1E(A,K,N)

   A - Vector to be sorted - real - input/output.
   K - Sort index key - integer - output
   N - Length of A and K

3.2.1.9 <u>Design Requirements</u>

a) Open core is defined at /DUM1XX/
b) No scratch files are used
c) DUMOD1 resides in LINKNS07
d) Open core for five GINO buffers is needed.
e) The layout for open core is as follows:

<u>Phase I</u>

COMMØN/DUMIXX/ Z

Z(1)	Column of MGG	NTYPE*G-set
	FREE	
Z(ICSTM)	CSTM DATA	LCSTM
Z(IBUF5)	M2GG	GINO BUFFER
Z(IBUF4)	M1GG	GINO BUFFER
Z(IBUF3)	B1GG	GINO BUFFER
Z(IBUF2)	BGPDT	GINO BUFFER
Z(IBUF1)	CSTM/MGG	GINO BUFFER+1

Phase II

COMMON/DUMIXX/Z

Z(IFRL)	FRL DATA	NF
Z(INDEX)	SORT INDEX KEY	3*NF
Z(IFRLX)	FRLX DATA	3*NF
Z(IPDZ)	PDZERO DATA	3*NF
	FREE	
Z(IBUF3)	PDZERO	GINO BUFFER
Z(IBUF2)	CASELL/FRLX	GINO BUFFER
Z(IBUF1)	FRL	GINO BUFFER+1

Phase III

COMMON/DUMIXX/Z

Z(IFRL)	FRL DATA	NFS	
Z(INDEX)	SORT INDEX	3*NFSX	
Z(ITAB)	PRETAB TABLE DATA	NTABL	
Z(N1)	BASE MATRIX	(3*NFSX)*2	Complex
Z(N2)	BASE1 MATRIX	(3*NFSX)*2	Complex
Z(N3)	COLUMN OF BASEXG	(G-set)*2	Complex
	FREE		
Z(IBUF1)	DIT/BASEXG	GINO BUFFER+1	

3.2.1.10 Diagnostic Messages

The following fatal error messages may occur:

3001, 3002, 3003, 3008 and 3031.

3.2.2 Functional Module DUMMOD2

3.2.2.1 Entry Point: DUMOD2

3.2.2.2 Purpose

To generate tables FRL and FOL and matrices REORDER1 and REORDER2 to be used in a forced vibration response analysis of rotating cyclic structures. Parameters LMAS, NTSTEPS, FLMAX, NORO1 and NORO2 are also computed.

3.2.2.3 DMAP Calling Sequence

```
DUMMOD2  TOL,,,,,,,/FRL, FOL, REORDER1, REORDER2,,,,/V,Y,NSEGS/V,Y,
         CYCIO/V,Y,LMAX=-1/V,N,FKMAX/V,N,FLMAX/V,N,NTSTEPS/V,N,NORO1/
         V,N,NORO2 $
```

3.2.2.4 Input Data Blocks

TOL - Time output list.

NOTES: 1. TOL must be present

3.2.2.5 Output Data Blocks

FRL - Frequency Response List
FOL - Frequency Output List
REORDER1 - Load reordering matrix for time-dependent frequency response problems.
REORDER2 - Load reordering matrix for time-dependent frequency response problems.

NOTES: 1. FRL and FOL cannot be purged.

3.2.2.6 Parameters

NSEGS - Input-integer-no default. NSEGS is the number of identical segments in the structural model.

CYCIO - Input-integer-no default. The value of this parameter specifies the form of the input and output data for cyclic structures. A value of +1 is used to specify physical segment representation and a value of -1 for cyclic transformation representation.

LMAX - Input/output-integer-default. LMAX specifies the maximum time-harmonic index for cyclic structures. The default value is NTSTEPS/2, where NTSTEPS is defined below.

FKMAX - Input-integer-no default. FKMAX is a function of parameter KMAX.
FLMAX - Output-integer-no default. FLMAX is a function of parameter LMAX.

NTSTEPS - Output-integer-no default. The number of time steps from data block TOL.

NORO1 - Output-integer-no default. NORO1=-1 if matrix REORDER1 is not generated, +1 otherwise.

NORO2 - Output-integer-no defualt. NORO2=-1 if matrix REORDER2 is not generated, +1 otherwise.

3.2.2.7 Method

Computations proceed in three phases. Parameters NTSTEPS, LMAX and FLMAX are computed in Phase I. Data blocks FRL and FOL are generated and output in Phase II and matrix data blocks REORDER1 and REORDER2 and their respective parameters NORO1 and NORO2 are generated and output in Phase III.

3.2.2.7.1 Computation of Parameters NTSTEPS, LMAX and FLMAX

Data block TOL is open and the list of output times is read from the header record and stored for use by Phase II. Let NTIMES be the number of times read.

a) Parameter NTSTEPS

If CYCIO=-1, then NTSTEPS=(NTIMES*FKMAX)/FKMAX
If CYCIO=+1, then NTSTEPS=(NTIMES*NSEGS)/NSEGS

b) Parameter LMAX

If LMAX<0, then the default value of LMAX is set equal to NTSTEPS/2.

c) Parameter FLMAX

If NTSTEPS is even and LMAX=NTSTEPS/2, then FLMAX=NTSTEPS, otherwise FLMAX=2*LMAX+1.

3.2.2.7.2 Generation of tables FOL and FRL

The list of times read from TOL are now converted to the frequency domain. The number of frequencies, NFREQ, is set equal to FLMAX.

Let PERIOD = TIME(2) + TIME(NTSTEPS)

then, FOL(1) = 0.0
FOL(i) = $(i-{}^{1}/_{2})*({}^{1.0}/_{PERIOD})$ for i = 2,4,6,...,NFREQ
and FOL(j) = FOL(j-1) for j = 3,5,7,...,NFREQ-1

Data block FOL is then output and data block FRL is then generated from FOL by converting the FOL frequencies in hertz to FRL frequencies in radians, FRL(i) = FOL(i)*2π for i = 1, NFREQ.

3.2.2.7.3 Computation of parameters NORO1 and NORO2 and matrices REORDER1 and REORDER2.

REORDER 1 and REORDER2 are used for reordering columns of a matrix by post-multiplying the matrix whose columns are to be reordered. Routine DUMO2A is called twice, once to generate and output REORDER1 and once to generate and output REORDER2. See the subroutine description of DUMO2A for details.

3.2.2.8 Subroutines

DUMOD2 uses standard NASTRAN GINO routines and utility routines.

3.2.2.8.1 Subroutine Name: DUMO2A

1. Entry Point: DUMO2A

2. Purpose: To generate and output column reordering matrices REORDER1 and REORDER2 and to compute parameters NORO1 and NORO2.

3. Calling Sequence: CALL DUMO2A(FILE, KK1, KK2, NORO, BUFFER)

   FILE - GINO file number of REORDER1 or REORDER2 - integer - input.

   KK1 - Reordering row index - integer - input.

   KK2 - Reordering column index - integer - input.

   NORO - NORO=+1 if reordering matrix was generated, -1 otherwise - integer - output.

   BUFFER - GINO buffer - real - input

4. Method: If KK1 = 1 or KK2 = 1 then set parameter NORO=-1, otherwise set parameter NORO=+1 to indicate that the reordering matrix was generated. If NORO=-1, then return otherwise continue processing. Generate a real single precision reordering matrix of order KK1*KK2 by KK1*KK2. This matrix can be used to reorder columns of another matrix by post-multiplying the matrix whose columns are to be reordered. Column i of the reordering matrix contains a 1.0 in row j if column j is to become column i of the reordered matrix. For example, if column 5 is to become column 1 of the new matrix then the reordering matrix contains a 1.0 in row 5 of column 1.

3.2.2.9 Design Requirements

a) Open core is defined at /DUM2XX/
b) DUMOD2 resides in LINKNS07
c) No scratch files are used
d) Open core for one BUFFER+1 is required.

The layout of open core is as follows:

COMMON/DUM2XX/

Z(ITOL)	TOL TIME DATA	NTIMES
Z(IFOL)	FOL/FRL DATA	FLMAX
	FREE	
Z(IBUF1)	TOL/FOL/FRL/REORDER	GINO BUFFER+1

3.2.2.10 <u>Diagnostic Messages</u>

The following fatal error messages may occur: 3001, 3002, 3008, 3037

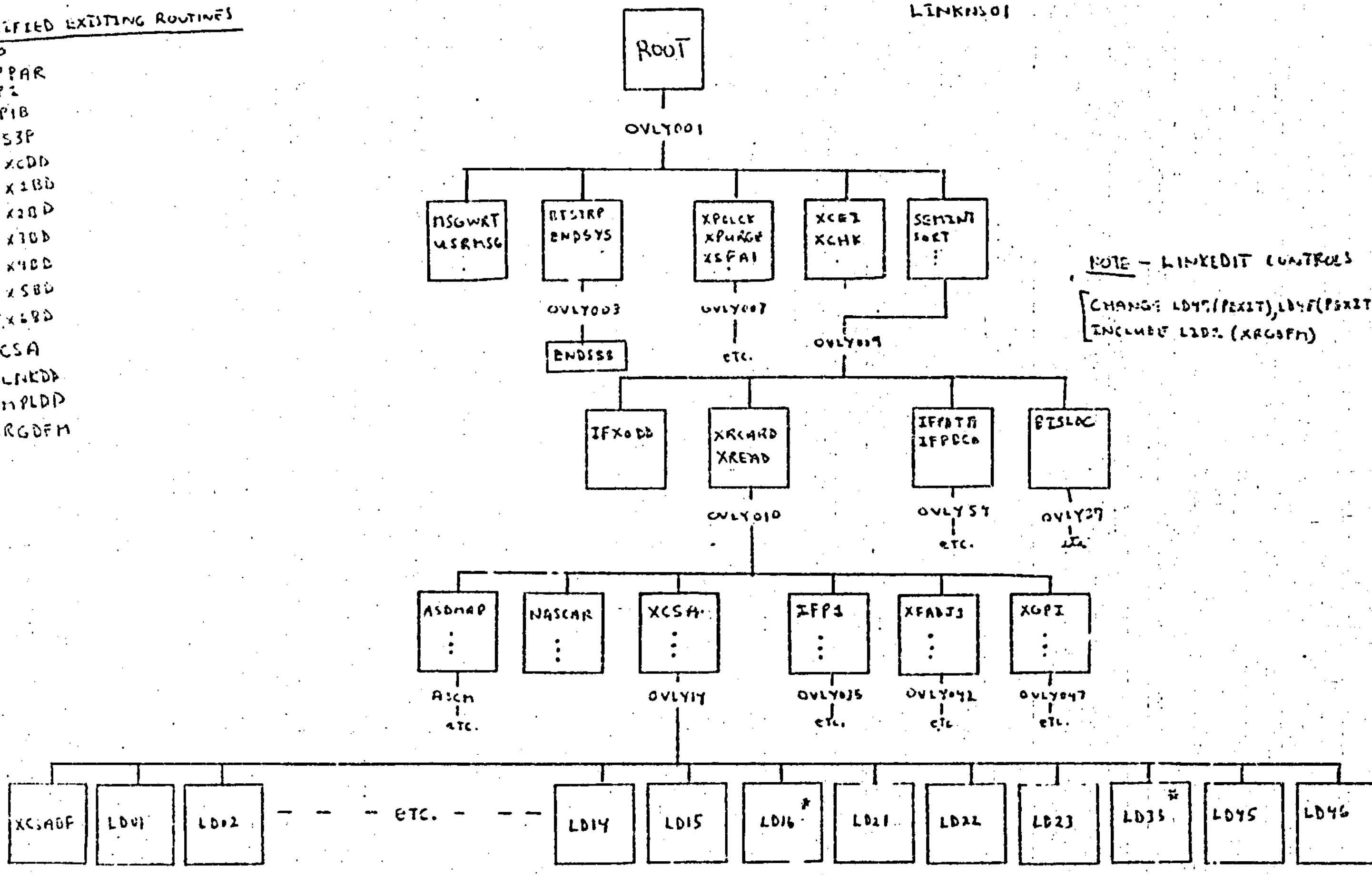
3.3 OVERLAY CHARTS

3.3.1 IBM OVERLAY CHARTS FOR NASTRAN LINKS 1, 6, 7, 9, 10, 11

NASTRAN L17.7 (IBM)
LINKNS01

MODIFIED EXISTING ROUTINES

IFP
IFPPAR
IFP2
IFP1B
IFS3P
IFXCDD
IFX1BD
IFX2BD
IFX3BD
IFX4BD
IFX5BD
IFX6BD
XCSA
XLNKDD
XMPLDD
XRGDFM



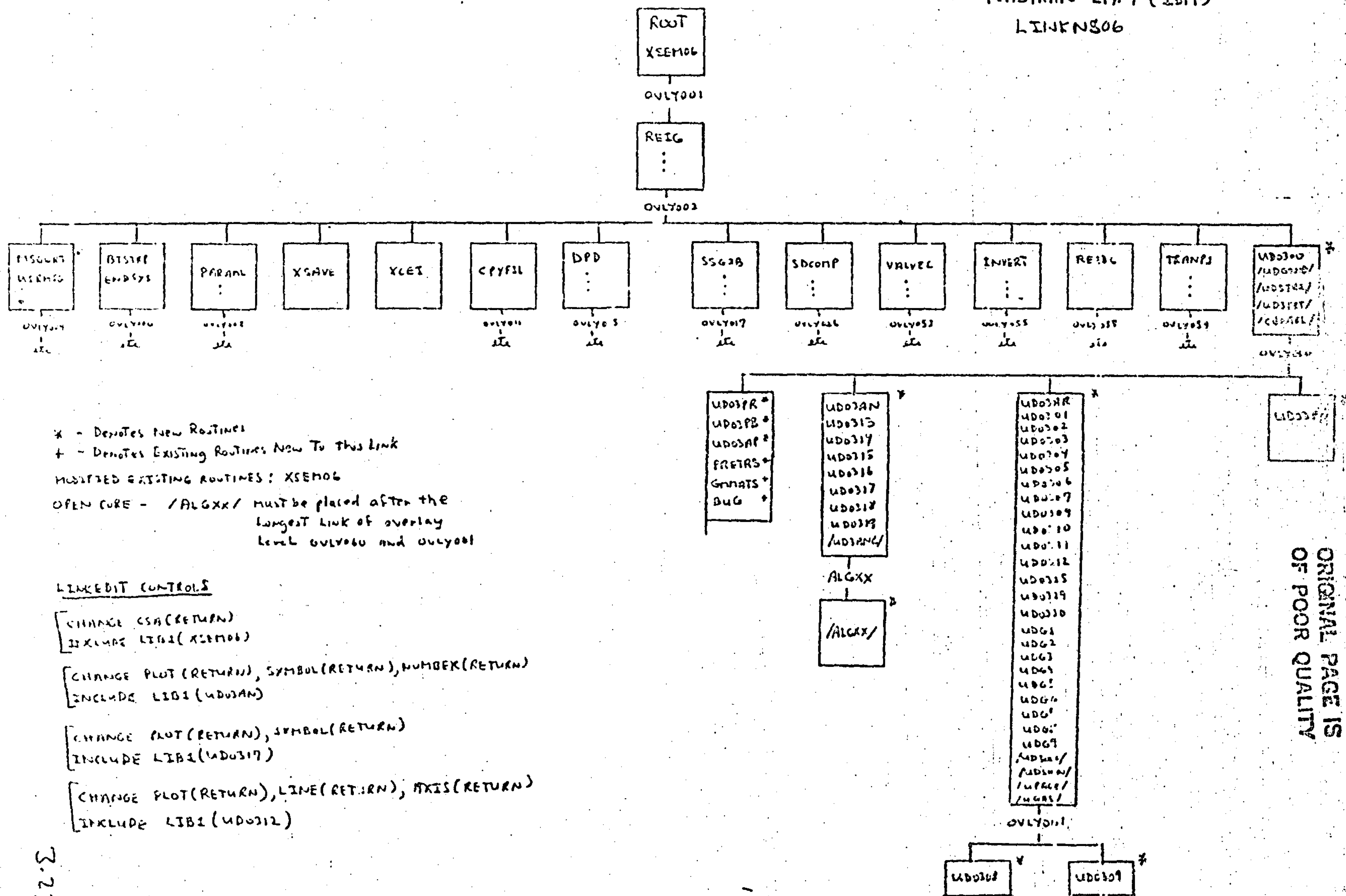
NOTE – LINKEDIT CONTROLS

CHANGE LD47(PSXIT), LD45(PSXIT), LD45(PSXIT), [illegible]
INCLUDE LD15 (XRGDFM)

* – Denotes New Routines

3.22

NASTRAN L17.7 (IBM)
LINKNS06



* - Denotes New Routines
\+ - Denotes Existing Routines New To this Link

MODIFIED EXISTING ROUTINES: XSEM06

OPEN CORE - /ALGXX/ must be placed after the longest link of overlay level OVLY060 and OVLY001

LINKEDIT CONTROLS

CHANGE CSA(RETURN)
INCLUDE LIB1(XSEM06)

CHANGE PLOT(RETURN), SYMBOL(RETURN), NUMBER(RETURN)
INCLUDE LIB1(UDO3AN)

CHANGE PLOT(RETURN), SYMBOL(RETURN)
INCLUDE LIB1(UDO317)

CHANGE PLOT(RETURN), LINE(RETURN), AXIS(RETURN)
INCLUDE LIB1(UDO312)

3.23

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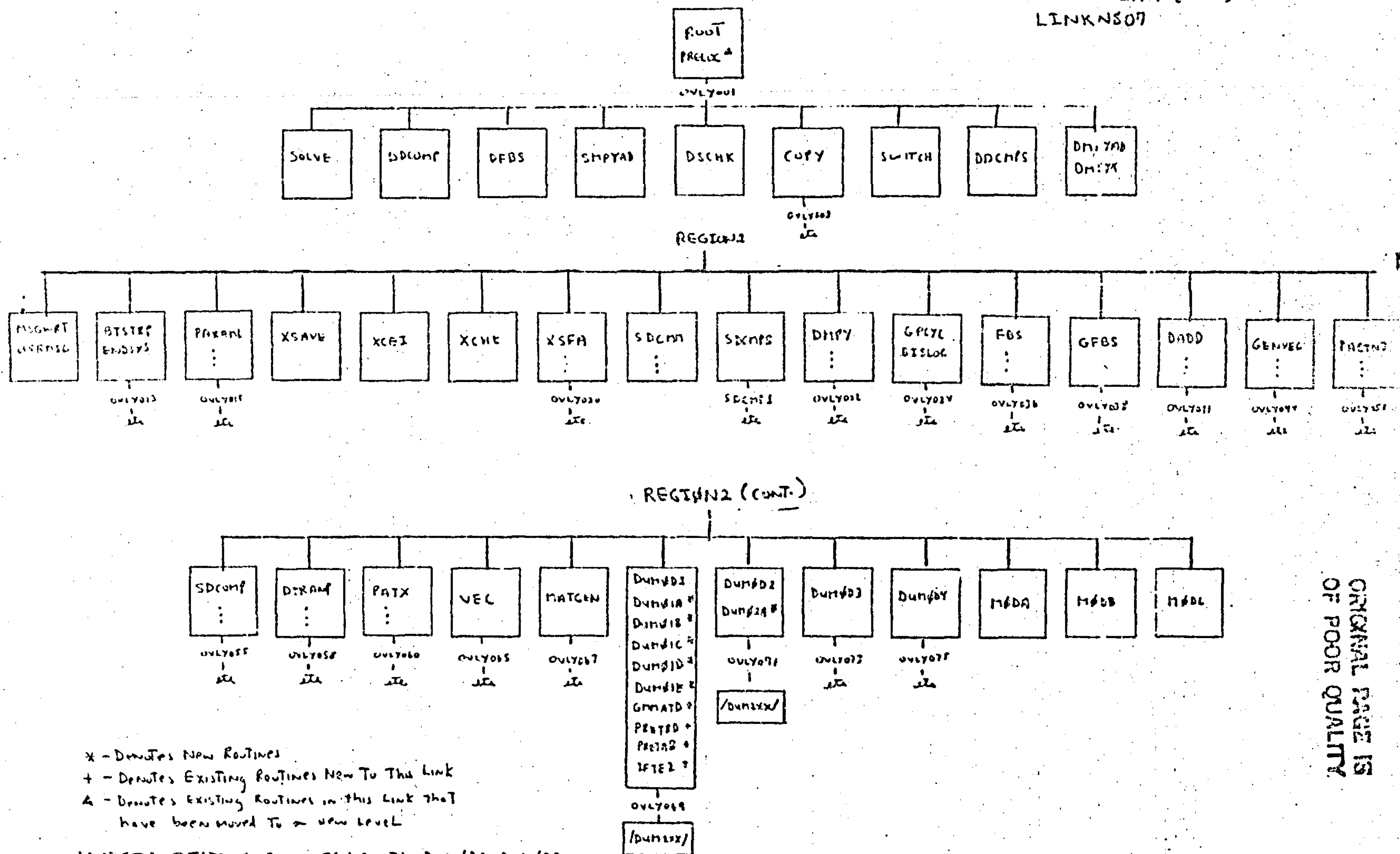
NASTRAN L17? (IBM)
LINKNS07



* - Denotes New Routines
+ - Denotes Existing Routines New To This Link
Δ - Denotes Existing Routines in this Link That have been moved To a new Level

MODIFIED EXISTING ROUTINES: CYCT1, DUMØD1, DUMØD2

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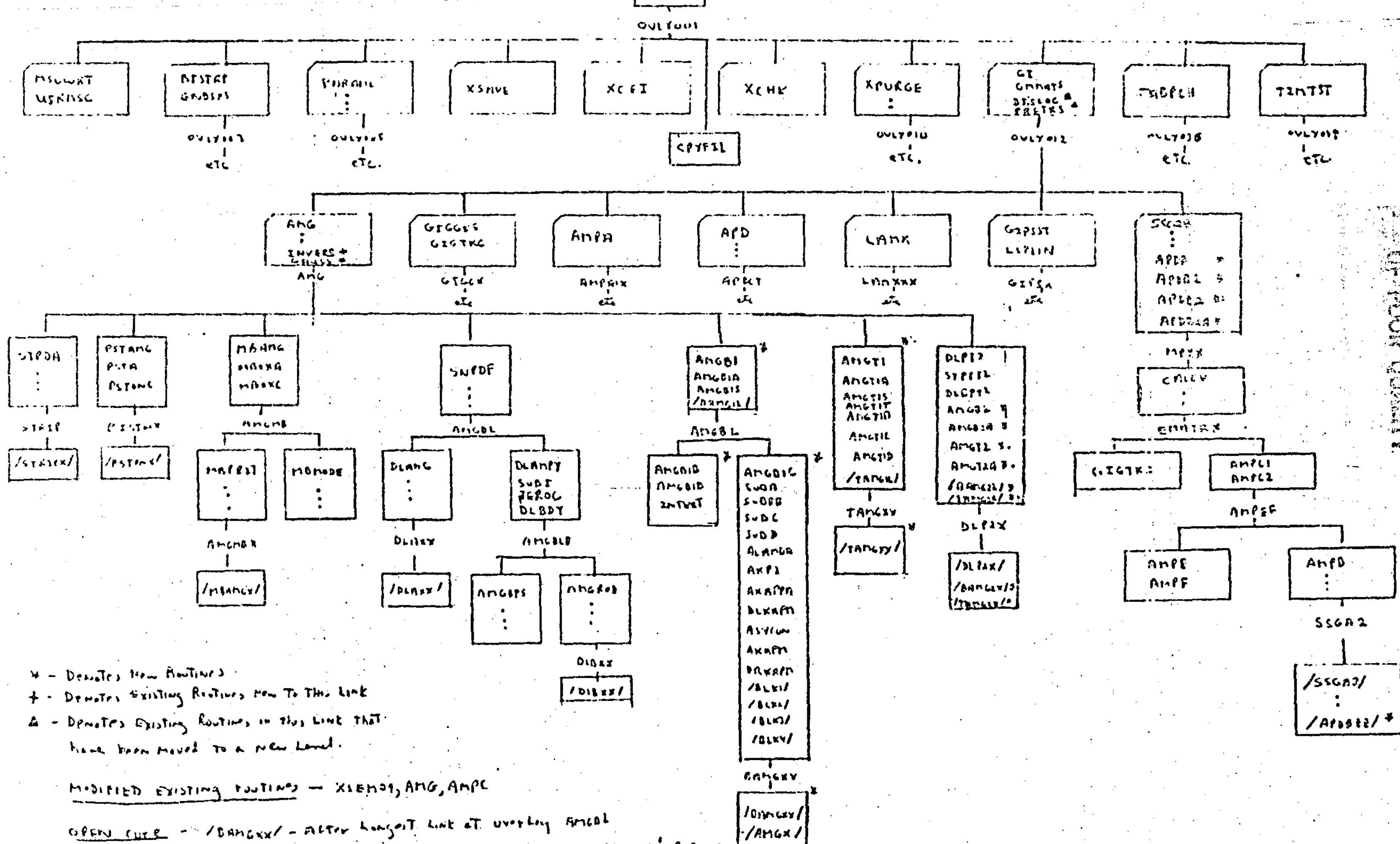
NASTRAN L17.7 (1811)
LINKNS09



* - Denotes New Routines

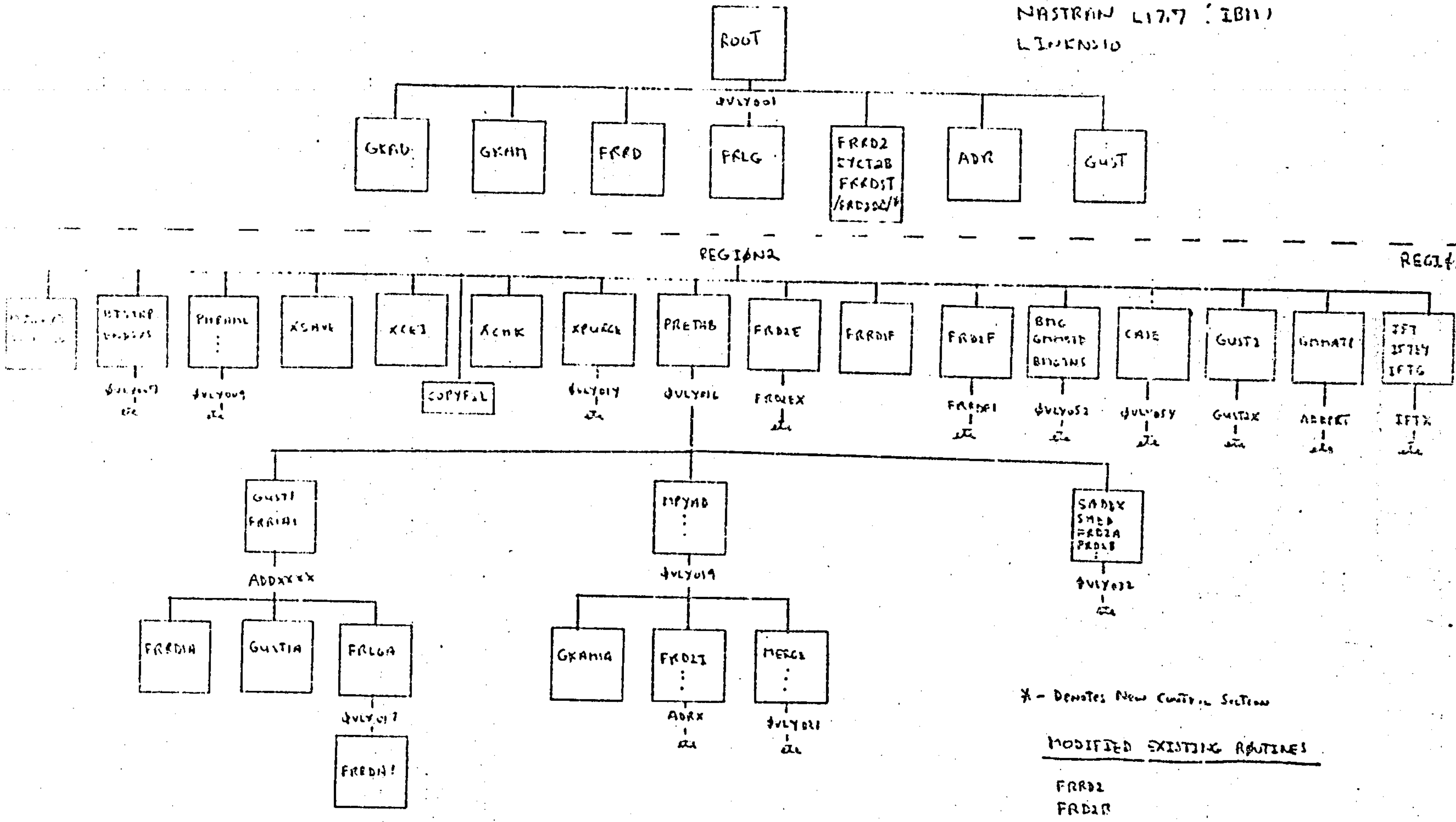
+ - Denotes Existing Routines New To This Link

Δ - Denotes Existing Routines in This Link That have been moved to a New Level.

MODIFIED EXISTING ROUTINES — XSEM09, AMG, AMPC

OPEN CORE NOTES - /BAMGXX/ - After Longest Link at overlay AMGBL
/AMGX/ - After Longest Link of overlay AMG 'Phase1' Routines
/DLFAX/ - After Longest Link of AMG 'Phase2' Routines

NASTRAN L17.7 (IBM)
LINKNS10

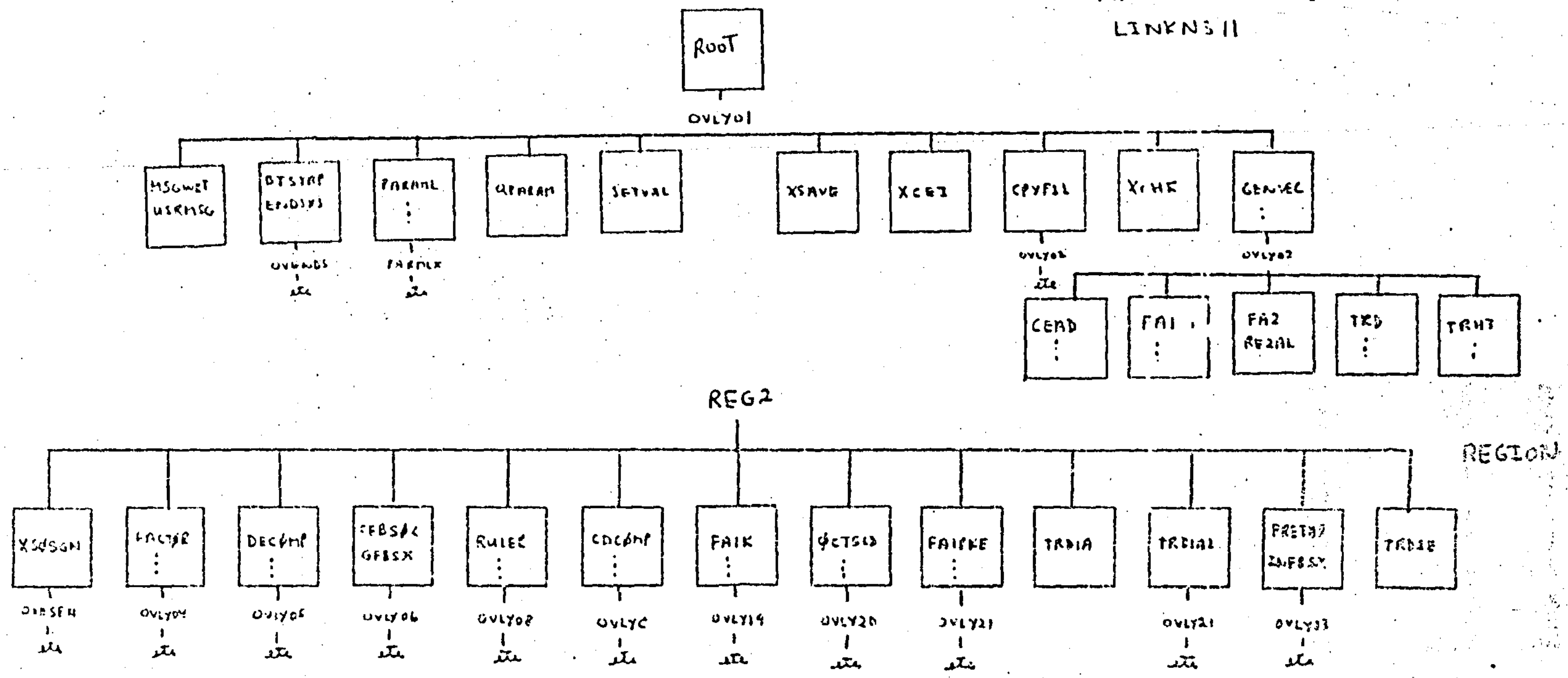


* - Denotes New Control Section

MODIFIED EXISTING ROUTINES

FRRD2
FRD2B
FRD2C

NASTRAN L17.7 (IBM)
LINKNS11



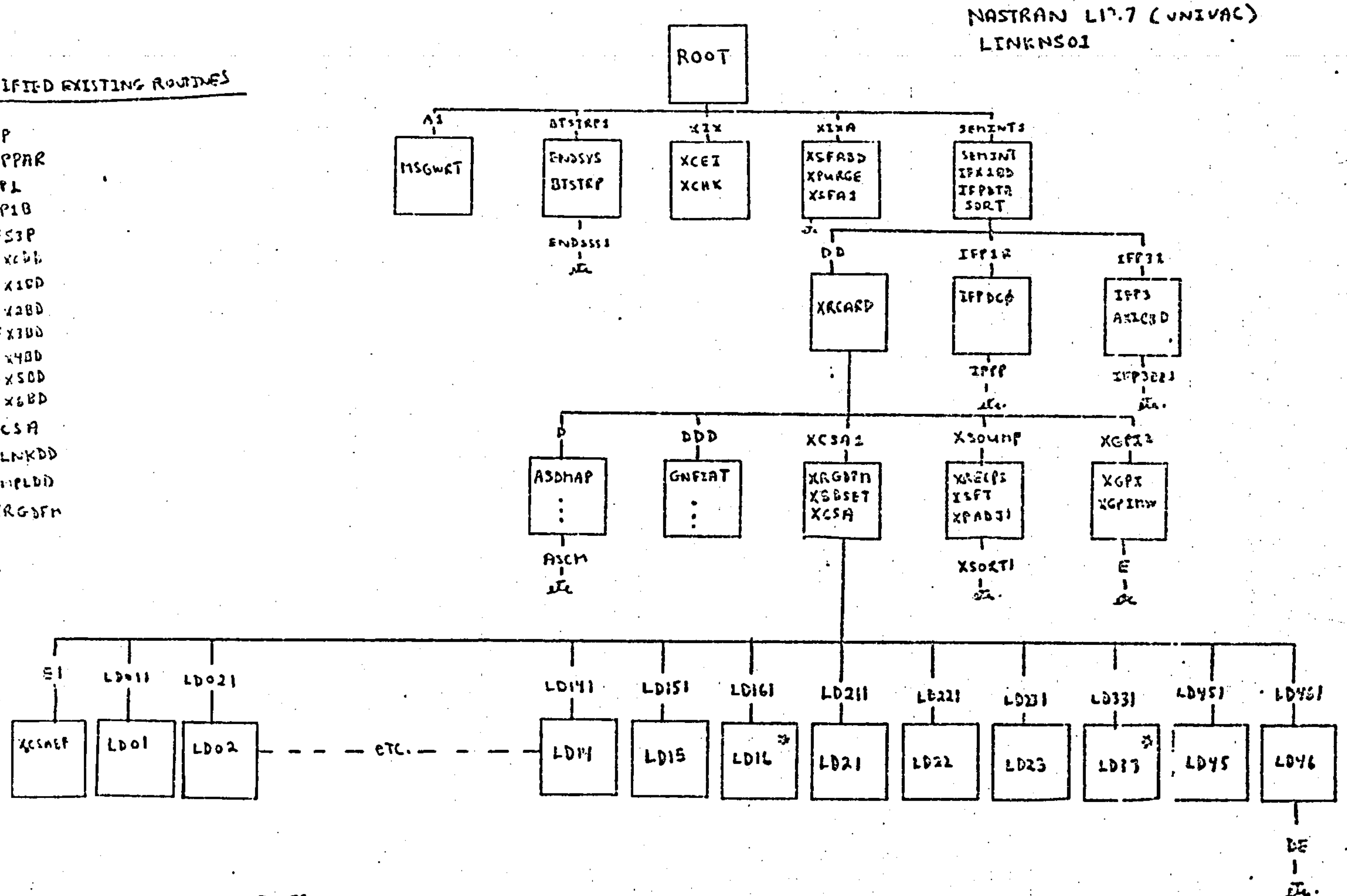
MODIFIED EXISTING ROUTINES: FA2

3.3.2 UNIVAC OVERLAY CHARTS FOR NASTRAN LINKS 1, 6, 7, 9, 10, 11

NASTRAN LV.7 (UNIVAC)
LINKNS01

MODIFIED EXISTING ROUTINES

IFP
IFPPAR
IFP1
IFP1B
IFS3P
IFXC00
IFX1BD
IFX2BD
IFX3BD
IFX4BD
IFX5BD
IFX6BD
XCSA
XLNKDD
XMPLDD
XRGDFM

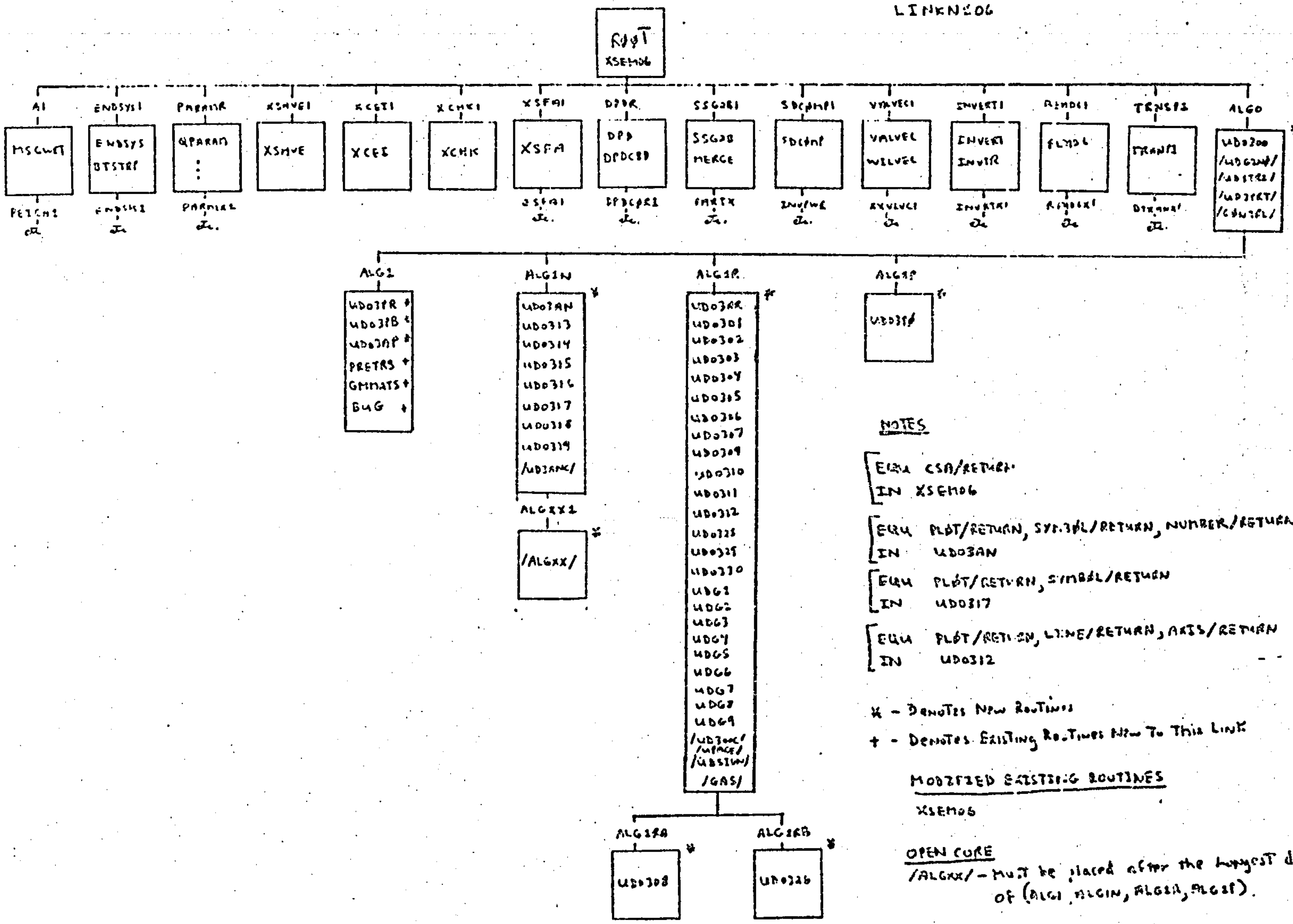


* DENOTES NEW ROUTINES

NOTE – EQU. LD47/RETURN, LD48/RETURN
EQU LD49/RETURN, LD50/RETURN
IN XRGDFM

C-2

NASTRAN LI.7 (UNIVAC)
LINKNS06



NOTES

EQU CSA/RETURN
IN XSEM06

EQU PLOT/RETURN, SYMBOL/RETURN, NUMBER/RETURN
IN UD03AN

EQU PLOT/RETURN, SYMBOL/RETURN
IN UD0317

EQU PLOT/RETURN, LINE/RETURN, AXIS/RETURN
IN UD0312

* - Denotes New Routines

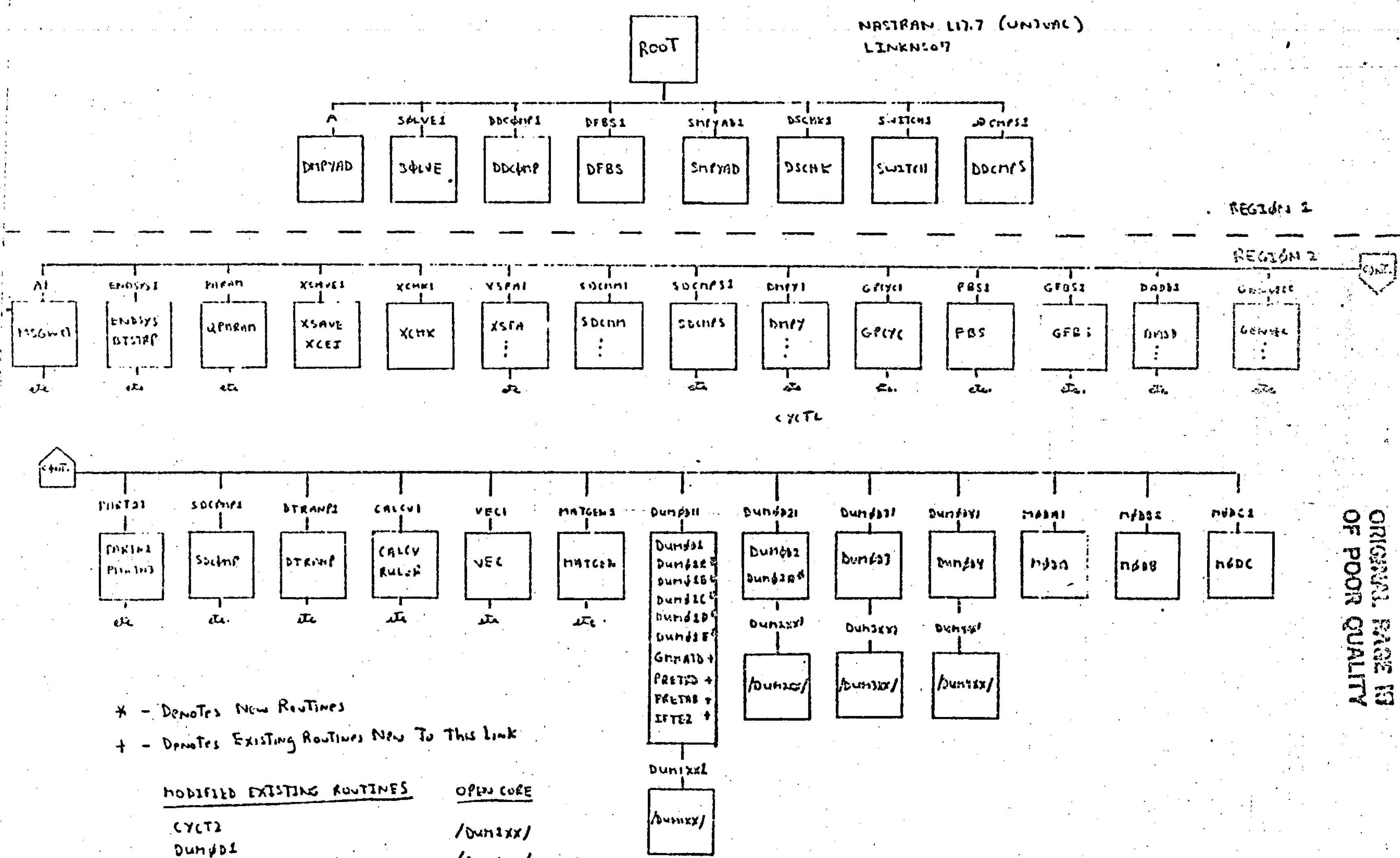
\+ - Denotes Existing Routines New To This Link

MODIFIED EXISTING ROUTINES

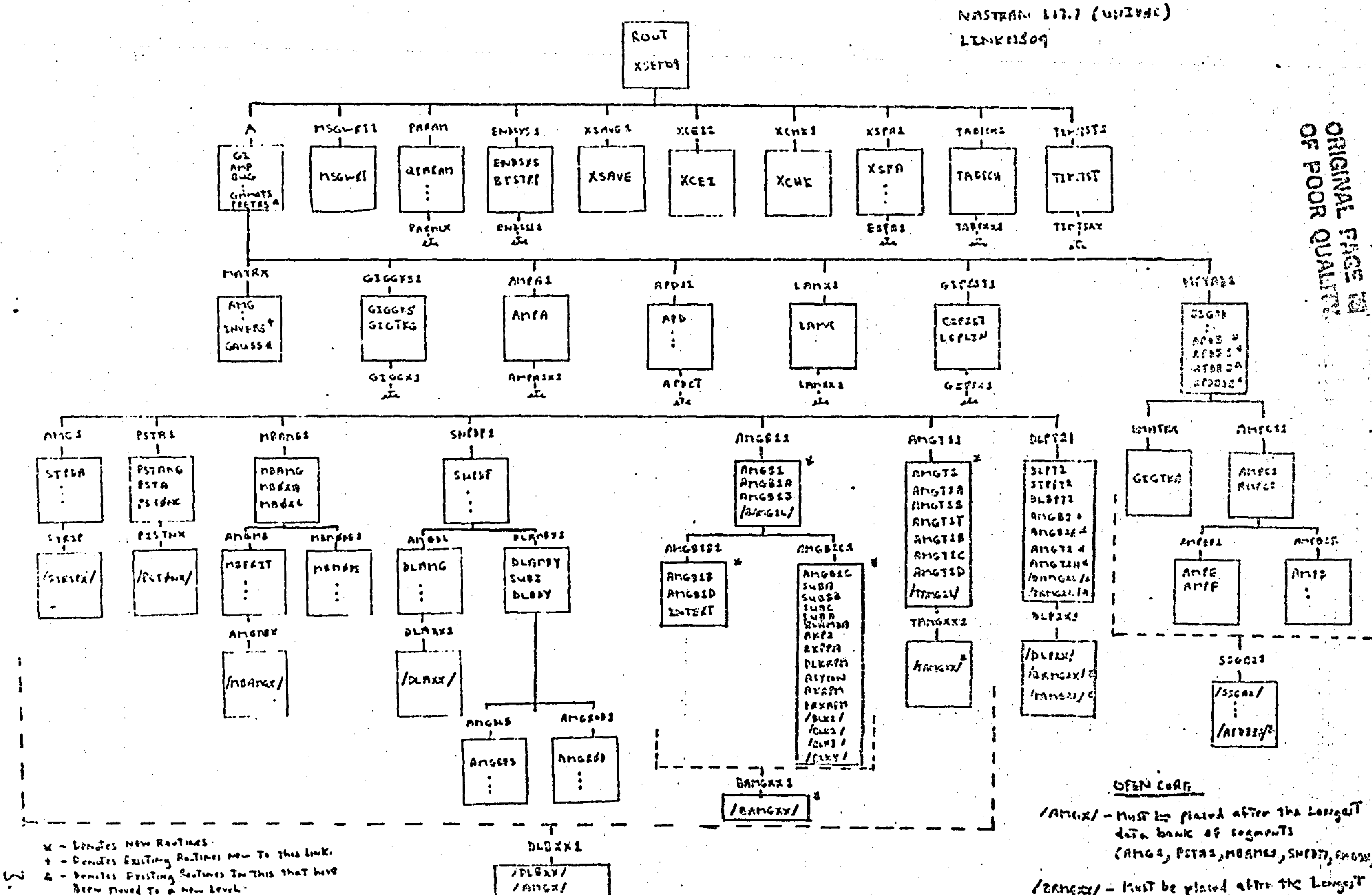
XSEM06

OPEN CORE

/ALGXX/ - Must be placed after the longest data block of (ALG1, ALG1N, ALG1R, ALG1P).


NASTRAN L17.7 (UNIVAC)
LINKNSO7
ROOT
DMPYAD
SOLVE
DDCMP
DFBS
SMPYAD
DSCHK
SWITCH
DDCMPS
REGION 1
REGION 2
XCHK
XSAVE
XCEI
XSFA
SDCMP
SDCMPS
DMPY
GPCYC
FBS
GFBS
CYCT2
DTRANP
CALCV
VEC
MATGEN
DUMØ1
DUMØ2
DUMØ3
DUMØ4
GMMATD +
PRETRD +
PRETRS +
IFTE2 +
/DUMIXX/
* - Denotes New Routines
+ - Denotes Existing Routines New To This Link
MODIFIED EXISTING ROUTINES
CYCT2
DUMØD1
DUMØD2
OPEN CORE
/DUMIXX/
/DUMIXX/

NASTRAN 17.7 (UNIVAC)
LINKNS09



* – Denotes New Routines
+ – Denotes Existing Routines New To This Link
4 – Denotes Existing Routines In This That have Been Moved To a New Level

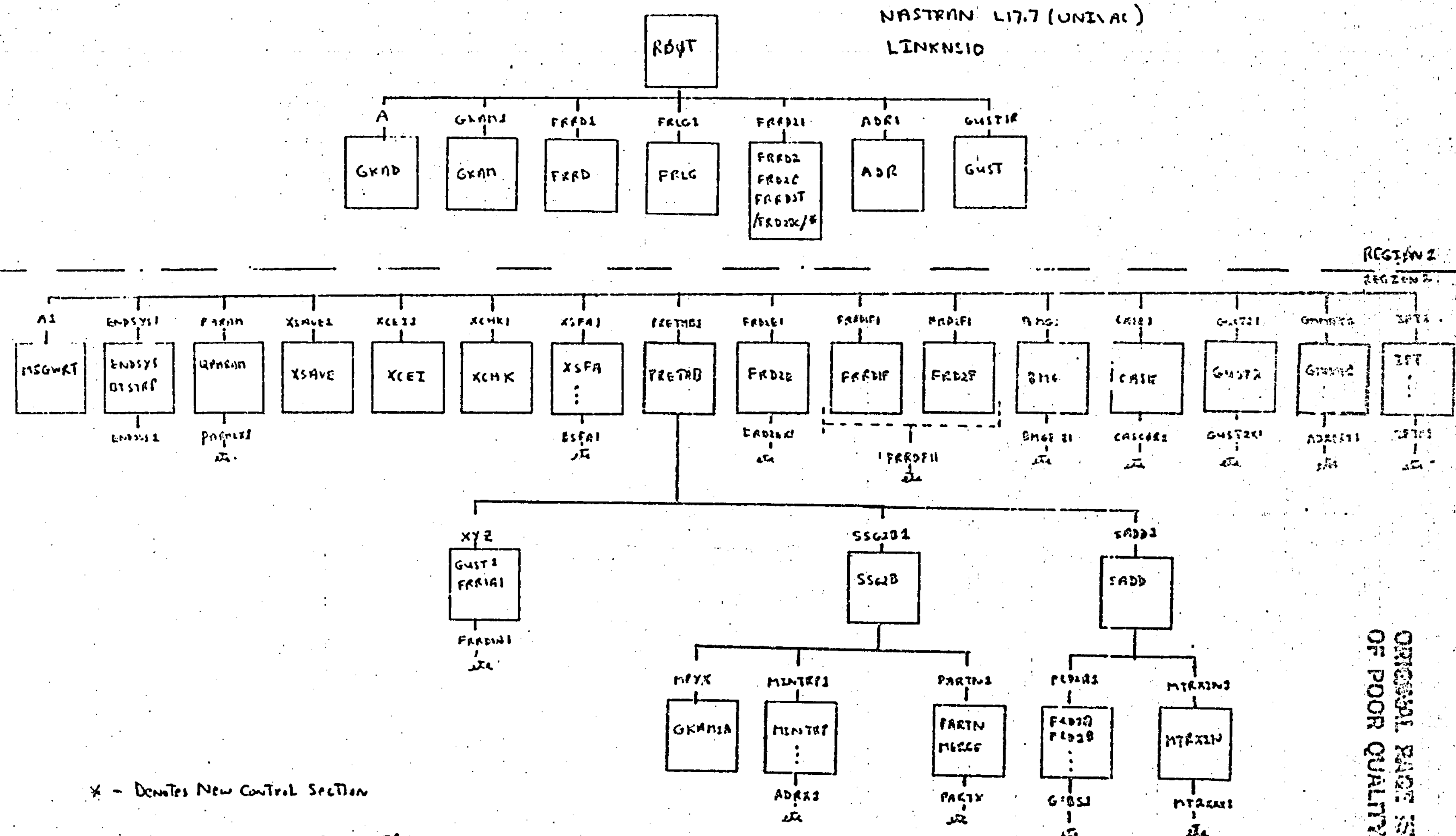
MODIFIED EXISTING ROUTINES: XSEM09, AMG, AMPC

OPEN CORE

/AMGXX/ – Must be placed after the Longest data bank of segments (AMGS, PSTRS, MBAMGS, SHFBTS, AMGB11, AMGT11)

/BAMGXX/ – Must be placed after the Longest data bank of segments (AMGB1S2, AMGB1CS)

NASTRAN L17.7 (UNIVAC)
LINKNS10



* - Denotes New Control Section

MODIFIED EXISTING ROUTINES

FRRD2
FRD2B
FRD2C

NASTRAN L17.7 (UNIVAC)
LINKNS11

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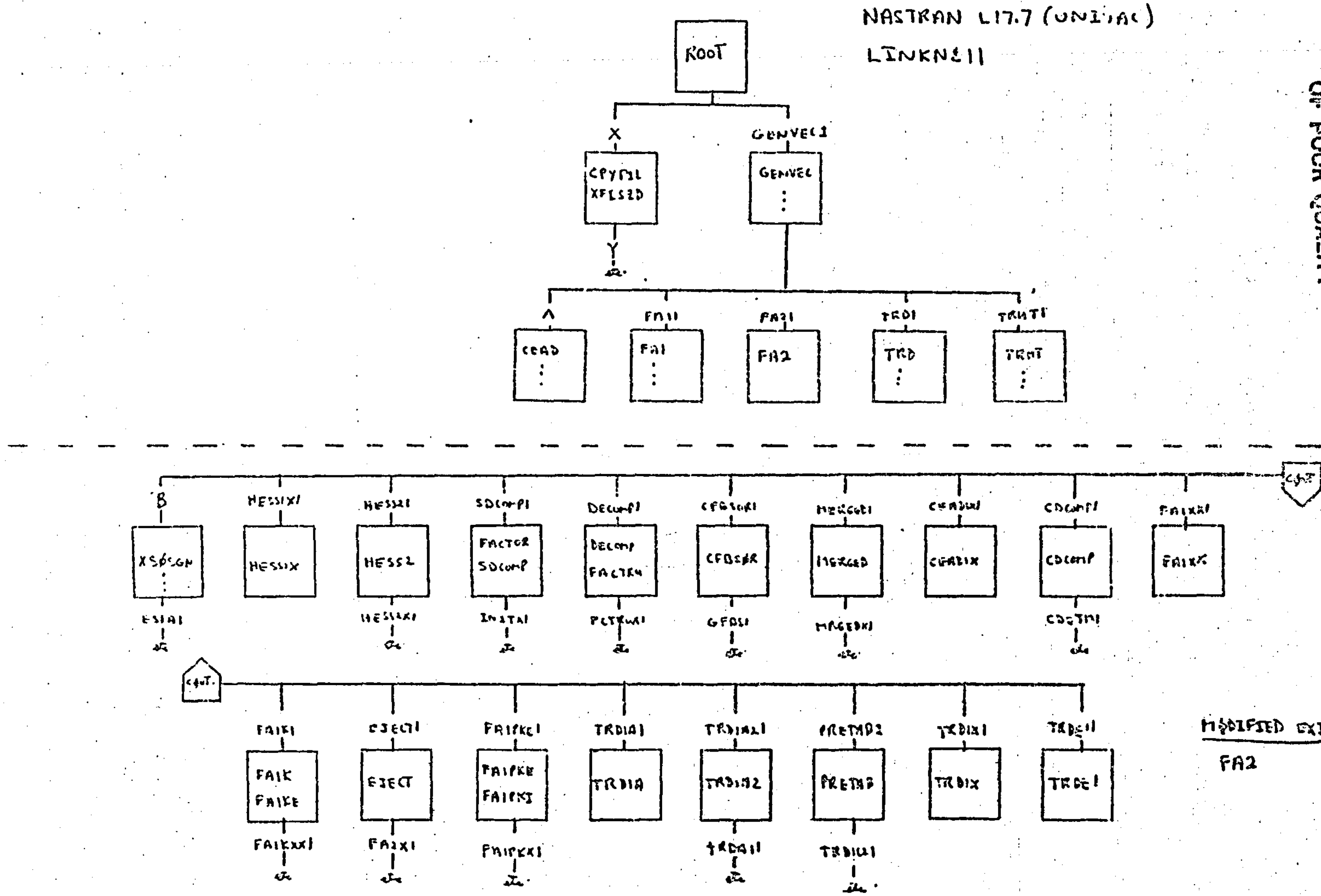

MODIFIED EXISTING ROUTINES
FA2

FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES

Frequency Response of a 12-Bladed Disc (Examples 1-5) by the Direct Method

A. General Description

Five inter-related examples are presented to illustrate various features of this new capability to conduct forced vibration analysis of rotating cyclic structures. A 12-bladed disc is used for demonstration.

The capability includes the effects of Coriolis and centripetal accelerations on the rotating structure which can be loaded with:

1. directly applied loads moving with the structure, and

2. inertial loads due to the translational acceleration of the axis of of rotation ('base' acceleration).

Example 1 is conducted on a finite element model of the complete structure (Figure 1). Examples 2 through 5 use a finite element model of one rotationally cyclic sector (Figure 2). Results of example 1 are used to verify some of the results obtained in the remaining examples. Table 1 summarizes the principal features demonstrated by these examples.

Steady-state frequency-dependent (sinusoidal) or time-dependent (periodic) loads are applied to selected grid point degrees of freedom. The specified loads can represent either the physical loads on various segments or their circumferential harmonic components. For illustration purposes only, the frequency band of excitation, 1700-1920 Hz, due to directly applied loads and base acceleration is selected to include the second bending mode of the disc for a circumferential harmonic index $k = 2$. The 'blade-to-blade' distribution of the directly applied loads also corresponds to $k = 2$. Table 2 lists the first few natural frequencies of the bladed disc for $k = 0$, 1 and 2. Modes for $k = 2$ are shown in Figure 3.

B. General Input

1. Parameters:

Diameter at blade tip	=	19.4 in.
Diameter at blade root	=	14.2 in.
Shaft diameter	=	4.0 in.

Disc thickness = 0.25 in.

Blade thickness = 0.125 in.

Young's modulus = 30.0×10^6 lbf/in.^{2}

Poisson's ratio = 0.3

Material density = 7.4×10^{-4} lbs-sec^2/in.^{4}

Uniform structural damping (g) = 0.02

2. Constraints:

All constraints are applied in body-fixed global coordinate system(s). All grid points on the shaft diameter are completely fixed. Rotational degrees of freedom θ_Z at remaining grid points are constrained to zero.

EXAMPLE 1

A. <u>Description</u>

This example uses the direct frequency response capability in NASTRAN, RF8, and forms the basis to verify some of the results of examples 2 through 5.

B. <u>Input</u>

1. Parameters:

   Same as general input parameters.

2. Constraints:

   Same as general input constraints.

3. Loads:

$$P(f;n) = A(f)\cos\left(\overline{n-1}\cdot \textcircled{2}\cdot\frac{2\pi}{\textcircled{12}}\right),$$

where n is the segment number,

$\textcircled{2}$ represents k = 2,

$\textcircled{12}$ represents the total number of segments in the bladed disc.

P is specified using RLOADi bulk data cards.

C. <u>Results</u>

Sample plots of grid point displacement and element stress response are shown in Figures 4 through 6. The expected behavior about a k = 2 natural frequency of the bladed disc can be seen in all these figures.

D. Driver Decks and Bulk Data

N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

```
ID        NASA,EXAMPLE1
APP       DISP
SOL       8
TIME      15    $ IBM 370/3031
DIAG      14,21
CEND
```

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FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 1   (FULL MODEL,FREQ LOADS)

KINDEX 2C TYPE LOADS

C A S E   C O N T R O L   D E C K   E C H O

```
$
TITLE = FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
SUBTITLE = BLADED DISC EXAMPLE 1       (FULL MODEL,FREQ LOADS)
LABEL = KINDEX 2C TYPE LOADS
$
   SPC    = 30
   FREQ   = 1
   DLOAD  = 1
OUTPUT
   SET 1 = 8,22,36,50,64,78,92,106,120,134,148,162,
           16,30,44,58,72,86,100,114,128,142,156,170,
           18,32,46,60,74,88,102,116,130,144,158,172
   OLOAD = 1
   DISP(SORT2,PHASE)    = ALL
   STRESS(SORT2,PHASE)  = ALL
OUTPUT(XYPLOT)
   PLOTTER NASTPLT, MODEL D,0
   XPAPER = 8.0
   YPAPER = 10.5
   XAXIS = YES
   YAXIS = YES
   XGRID LINES = YES
   YGRID LINES = YES
   CURVELINESYMBOL = 1
   YLOG = YES
   XTITLE =                                FREQUENCY (HERTZ)
   YTITLE =       GRID POINT DISPLACEMENTS ( MAGNITUDE,INCH )
   TCURVE = 14(T3RM),18(T3RM),95(T3RM)
  XYPLOT,XYPRINT DISP RESPONSE    /14(T3RM),18(T3RM),95(T3RM)
   YTITLE =             ELEMENT STRESSES ( MAGNITUDE,PSI )
   TCURVE = 11(3),11(5),11(7),11(10),11(12),11(14)
  XYPLOT,XYPRINT STRESS RESPONSE   /11(3),11(5),11(7),
                                    11(10),11(12),11(14)
   TCURVE = 109(3),109(5),109(7),109(10),109(12),109(14)
  XYPLOT,XYPRINT STRESS RESPONSE   /109(3),109(5),109(7),
                                    109(10),109(12),109(14)
BEGIN BULK
```

SER INFORMATION MESSAGE 207, BULK DATA NOT SORTED,XSORT WILL RE-ORDER DECK.

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S O R T E D   B U L K   D A T A   E C H O

. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
CORD2C	1		.0	.0	.0	1.0	.0	.0	&COR_2
&COR12	0.0	1.0	0.0						
CQUAD2	4	2	2	3	7	6			
CQUAD2	5	2	6	7	12	11			
CQUAD2	6	2	3	4	8	7			
CQUAD2	7	2	7	8	13	12			
CQUAD2	8	2	4	5	9	8			
CQUAD2	10	2	8	15	14	13			
CQUAD2	11	3	9	16	18	15			
CQUAD2	12	3	16	17	19	18			
CQUAD2	16	2	11	12	21	20			
CQUAD2	17	2	20	21	26	25			
CQUAD2	18	2	12	13	22	21			
CQUAD2	19	2	21	22	27	26			
CQUAD2	20	2	13	14	23	22			
CQUAD2	22	2	22	29	28	27			
CQUAD2	23	3	23	30	32	29			
CQUAD2	24	3	30	31	33	32			
CQUAD2	28	2	25	26	35	34			
CQUAD2	29	2	34	35	40	39			
CQUAD2	30	2	26	27	36	35			
CQUAD2	31	2	35	36	41	40			
CQUAD2	32	2	27	28	37	36			
CQUAD2	34	2	36	43	42	41			
CQUAD2	35	3	37	44	46	43			
CQUAD2	36	3	44	45	47	46			
CQUAD2	40	2	39	40	49	48			
CQUAD2	41	2	48	49	54	53			
CQUAD2	42	2	40	41	50	49			
CQUAD2	43	2	49	50	55	54			
CQUAD2	44	2	41	42	51	50			
CQUAD2	46	2	50	57	56	55			
CQUAD2	47	3	51	58	60	57			
CQUAD2	48	3	58	59	61	60			
CQUAD2	52	2	53	54	63	62			
CQUAD2	53	2	62	63	68	[illegible]			
CQUAD2	54	2	54	55	64	63			
CQUAD2	55	2	63	64	69	68			
CQUAD2	56	2	55	56	65	64			
CQUAD2	58	2	64	71	70	69			
CQUAD2	59	3	65	72	74	71			
CQUAD2	60	3	72	73	75	74			
CQUAD2	64	2	67	68	77	76			
CQUAD2	65	2	76	77	82	81			
CQUAD2	66	2	68	69	78	77			
CQUAD2	67	2	77	78	83	82			
CQUAD2	68	2	69	70	79	78			
CQUAD2	70	2	78	85	84	83			
CQUAD2	71	3	79	86	88	85			
CQUAD2	72	3	86	87	89	88			

SORTED BULK DATA ECHO

. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
CQUAD2	76	2	81	82	91	90			
CQUAD2	77	2	90	91	96	95			
CQUAD2	78	2	82	83	92	91			
CQUAD2	79	2	91	92	97	96			
CQUAD2	80	2	83	84	93	92			
CQUAD2	82	2	92	99	98	97			
CQUAD2	83	3	93	100	102	99			
CQUAD2	84	3	100	101	103	102			
CQUAD2	88	2	95	96	105	104			
CQUAD2	89	2	104	105	110	109			
CQUAD2	90	2	96	97	106	105			
CQUAD2	91	2	105	106	111	110			
CQUAD2	92	2	97	98	107	106			
CQUAD2	94	2	106	113	112	111			
CQUAD2	95	3	107	114	116	113			
CQUAD2	96	3	114	115	117	116			
CQUAD2	100	2	109	110	119	118			
CQUAD2	101	2	118	119	124	123			
CQUAD2	102	2	110	111	120	119			
CQUAD2	103	2	119	120	125	124			
CQUAD2	104	2	111	112	121	120			
CQUAD2	106	2	120	127	126	125			
CQUAD2	107	3	121	128	130	127			
CQUAD2	108	3	128	129	131	130			
CQUAD2	112	2	123	124	133	132			
CQUAD2	113	2	132	133	138	137			
CQUAD2	114	2	124	125	134	133			
CQUAD2	115	2	133	134	139	138			
CQUAD2	116	2	125	126	135	134			
CQUAD2	118	2	134	141	140	139			
CQUAD2	119	3	135	142	144	141			
CQUAD2	120	3	142	143	145	146			
CQUAD2	124	2	137	138	147	146			
CQUAD2	125	2	146	147	152	151			
CQUAD2	126	2	138	139	148	147			
CQUAD2	127	2	14[illegible]	148	153	152			
CQUAD2	128	2	139	140	149	148			
CQUAD2	130	2	148	155	154	153			
CQUAD2	131	3	149	156	158	156			
CQUAD2	132	3	156	157	159	158			
CQUAD2	136	2	151	152	161	160			
CQUAD2	137	2	160	161	3	2			
CQUAD2	138	2	152	153	162	161			
CQUAD2	139	2	161	162	4	3			
CQUAD2	140	2	153	154	163	162			
CQUAD2	142	2	162	169	5	4			
CQUAD2	143	3	163	170	172	169			
CQUAD2	144	3	170	171	173	172			
CTRIA2	1	1	1	6	10				
CTRIA2	2	1	1	2	6				

S O R T E D   B U L K   D A T A   E C H O

. 1 .. 2 .. 3 .. 4 .. 5 .. 6 .. 7 .. 8 .. 9 .. 10 .

CTRIA2	3	1	10	6	11
CTRIA2	9	1	8	9	15
CTRIA2	13	1	10	20	24
CTRIA2	14	1	10	11	20
CTRIA2	15	1	24	20	25
CTRIA2	21	1	22	23	29
CTRIA2	25	1	24	34	38
CTRIA2	26	1	24	25	34
CTRIA2	27	1	38	34	39
CTRIA2	33	1	36	37	43
CTRIA2	37	1	38	48	52
CTRIA2	38	1	38	39	48
CTRIA2	39	1	52	48	53
CTRIA2	45	1	50	51	57
CTRIA2	49	1	52	62	66
CTRIA2	50	1	52	53	62
CTRIA2	51	1	66	62	67
CTRIA2	57	1	64	65	71
CTRIA2	61	1	66	76	80
CTRIA2	62	1	66	67	76
CTRIA2	63	1	80	76	81
CTRIA2	69	1	78	79	85
CTRIA2	73	1	80	90	94
CTRIA2	74	1	80	81	90
CTRIA2	75	1	94	90	95
CTRIA2	81	1	92	93	99
CTRIA2	85	1	94	104	108
CTRIA2	86	1	94	95	104
CTRIA2	87	1	108	104	109
CTRIA2	93	1	106	107	113
CTRIA2	97	1	108	118	122
CTRIA2	98	1	108	109	118
CTRIA2	99	1	122	118	123
CTRIA2	105	1	120	121	127
CTRIA2	109	1	122	132	136
CTRIA2	110	1	122	123	132
CTRIA2	111	1	136	132	137
CTRIA2	117	1	134	135	141
CTRIA2	121	1	136	146	150
CTRIA2	122	1	136	137	146
CTRIA2	123	1	150	146	151
CTRIA2	129	1	148	149	155
CTRIA2	133	1	150	160	1
CTRIA2	134	1	150	151	160
CTRIA2	135	1	1	160	2
CTRIA2	141	1	162	163	169
DAREA	1	8	3	-1.0	
DAREA	1	16	3	1.0	
DAREA	1	18	3	1.0	
DAREA	1	22	3	-0.5	

S O R T E D   B U L K   D A T A   E C H O

1	2	3	4	5	6	7	8	9	10
DAREA	1	30	3	.5					
DAREA	1	32	3	.5					
DAREA	1	36	3	.5					
DAREA	1	44	3	-0.5					
DAREA	1	46	3	-0.5					
DAREA	1	50	3	1.0					
DAREA	1	58	3	-1.0					
DAREA	1	60	3	-1.0					
DAREA	1	64	3	.5					
DAREA	1	72	3	-0.5					
DAREA	1	74	3	-0.5					
DAREA	1	78	3	-0.5					
DAREA	1	86	3	.5					
DAREA	1	88	3	.5					
DAREA	1	92	3	-1.0					
DAREA	1	100	3	1.0					
DAREA	1	102	3	1.0					
DAREA	1	106	3	-0.5					
DAREA	1	114	3	.5					
DAREA	1	116	3	.5					
DAREA	1	120	3	.5					
DAREA	1	128	3	-0.5					
DAREA	1	130	3	-0.5					
DAREA	1	134	3	1.0					
DAREA	1	142	3	-1.0					
DAREA	1	144	3	-1.0					
DAREA	1	148	3	.5					
DAREA	1	156	3	-0.5					
DAREA	1	158	3	-0.5					
DAREA	1	162	3	-0.5					
DAREA	1	170	3	.5					
DAREA	1	172	3	.5					
FREQ	1	1700.0	1750.0	1777.6	1795.7	1823.854	1832.0	1850.1	&FR1
&FR1	1880.0	1920.0							
GRDSET		1				1			
GRID	1		2.0	30.0	.0				
GRID	2		3.1	30.0	.0				
GRID	3		4.3	30.0	.0				
GRID	4		5.2	30.0	.0				
GRID	5		7.1	30.0	.0				
GRID	6		3.1	45.0	.0				
GRID	7		4.3	45.0	.0				
GRID	8		5.2	45.0	.0				
GRID	9		7.1	40.0	.0				
GRID	10		2.0	60.0	.0				
GRID	11		3.1	60.0	.0				
GRID	12		4.3	60.0	.0				
GRID	13		5.2	60.0	.0				
GRID	14		7.1	60.0	.0				
GRID	15		7.1	50.0	.0				

S O R T E D   B U L K   D A T A   E C H O

. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10
GRID	16		8.5	40.0	-.25				
GRID	17		9.7	40.0	-.50				
GRID	18		8.5	50.0	.25				
GRID	19		9.7	50.0	.50				
GRID	20		3.100	75.000	0.				
GRID	21		4.300	75.000	0.				
GRID	22		5.200	75.000	0.				
GRID	23		7.100	70.000	0.				
GRID	24		2.000	90.000	0.				
GRID	25		3.100	90.000	0.				
GRID	26		4.300	90.000	0.				
GRID	27		5.200	90.000	0.				
GRID	28		7.100	90.000	0.				
GRID	29		7.100	80.000	0.				
GRID	30		8.500	70.000	-0.250				
GRID	31		9.700	70.000	-0.500				
GRID	32		8.500	80.000	0.250				
GRID	33		9.700	80.000	0.500				
GRID	34		3.100	105.000	0.				
GRID	35		4.300	105.000	0.				
GRID	36		5.200	105.000	0.				
GRID	37		7.100	100.000	0.				
GRID	38		2.000	120.000	0.				
GRID	39		3.100	120.000	0.				
GRID	40		4.300	120.000	0.				
GRID	41		5.200	120.000	0.				
GRID	42		7.100	120.000	0.				
GRID	43		7.100	110.000	0.				
GRID	44		8.500	100.000	-0.250				
GRID	45		9.700	100.000	-0.500				
GRID	46		8.500	110.000	0.250				
GRID	47		9.700	110.000	0.500				
GRID	48		3.100	135.000	0.				
GRID	49		4.300	135.000	0.				
GRID	50		5.200	135.000	0.				
GRID	51		7.100	130.000	0.				
GRID	52		2.000	150.000	0.				
GRID	53		3.100	150.000	0.				
GRID	54		4.300	150.000	0.				
GRID	55		5.200	150.000	0.				
GRID	56		7.100	150.000	0.				
GRID	57		7.100	140.000	0.				
GRID	58		8.500	130.000	-0.250				
GRID	59		9.700	130.000	-0.500				
GRID	60		8.500	140.000	0.250				
GRID	61		9.700	140.000	0.500				
GRID	62		3.100	165.000	0.				
GRID	63		4.300	165.000	0.				
GRID	64		5.200	165.000	0.				
GRID	65		7.100	160.000	0.				

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. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10
GRID	66		2.000	180.000	0.				
GRID	67		3.100	180.000	0.				
GRID	68		4.300	180.000	0.				
GRID	69		5.200	180.000	0.				
GRID	70		7.100	180.000	0.				
GRID	71		7.100	170.000	0.				
GRID	72		8.500	160.000	-0.250				
GRID	73		9.700	160.000	-0.500				
GRID	74		8.500	170.000	0.250				
GRID	75		9.700	170.000	0.500				
GRID	76		3.100	195.000	0.				
GRID	77		4.300	195.000	0.				
GRID	78		5.200	195.000	0.				
GRID	79		7.100	190.000	0.				
GRID	80		2.000	210.000	0.				
GRID	81		3.100	210.000	0.				
GRID	82		4.300	210.000	0.				
GRID	83		5.200	210.000	0.				
GRID	84		7.100	210.000	0.				
GRID	85		7.100	200.000	0.				
GRID	86		8.500	190.000	-0.250				
GRID	87		9.700	190.000	-0.500				
GRID	88		8.500	200.000	0.250				
GRID	89		9.700	200.000	0.500				
GRID	90		3.100	225.000	0.				
GRID	91		4.300	225.000	0.				
GRID	92		5.200	225.000	0.				
GRID	93		7.100	220.000	0.				
GRID	94		2.000	240.000	0.				
GRID	95		3.100	240.000	0.				
GRID	96		4.300	240.000	0.				
GRID	97		5.200	240.000	0.				
GRID	98		7.100	240.000	0.				
GRID	99		7.100	230.000	0.				
GRID	100		8.500	220.000	-0.250				
GRID	101		9.700	220.000	-0.500				
GRID	102		8.500	230.000	0.250				
GRID	103		9.700	230.000	0.500				
GRID	104		3.100	255.000	0.				
GRID	105		4.300	255.000	0.				
GRID	106		5.200	255.000	0.				
GRID	107		7.100	250.000	0.				
GRID	108		2.000	270.000	0.				
GRID	109		3.100	270.000	0.				
GRID	110		4.300	270.000	0.				
GRID	111		5.200	270.000	0.				
GRID	112		7.100	270.000	0.				
GRID	113		7.100	260.000	0.				
GRID	114		8.500	250.000	-0.250				
GRID	115		9.700	250.000	-0.500				

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. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10
GRID	116		8.500	260.000	0.250				
GRID	117		9.700	260.000	0.500				
GRID	118		3.100	285.000	0.				
GRID	119		4.300	285.000	0.				
GRID	120		5.200	285.000	0.				
GRID	121		7.100	280.000	0.				
GRID	122		2.000	300.000	0.				
GRID	123		3.100	300.000	0.				
GRID	124		4.300	300.000	0.				
GRID	125		5.200	300.000	0.				
GRID	126		7.100	300.000	0.				
GRID	127		7.100	290.000	0.				
GRID	128		8.500	280.000	-0.250				
GRID	129		9.700	280.000	-0.500				
GRID	130		8.500	290.000	0.250				
GRID	131		9.700	290.000	0.500				
GRID	132		3.100	315.000	0.				
GRID	133		4.300	315.000	0.				
GRID	134		5.200	315.000	0.				
GRID	135		7.100	310.000	0.				
GRID	136		2.000	330.000	0.				
GRID	137		3.100	330.000	0.				
GRID	138		4.300	330.000	0.				
GRID	139		5.200	330.000	0.				
GRID	140		7.100	330.000	0.				
GRID	141		7.100	320.000	0.				
GRID	142		8.500	310.000	-0.250				
GRID	143		9.700	310.000	-0.500				
GRID	144		8.500	320.000	0.250				
GRID	145		9.700	320.000	0.500				
GRID	146		3.100	345.000	0.				
GRID	147		4.300	345.000	0.				
GRID	148		5.200	345.000	0.				
GRID	149		7.100	340.000	0.				
GRID	150		2.000	0.000	0.				
GRID	151		3.100	0.000	0.				
GRID	152		4.300	0.000	0.				
GRID	153		5.200	0.000	0.				
GRID	154		7.100	0.000	0.				
GRID	155		7.100	350.000	0.				
GRID	156		8.500	340.000	-0.250				
GRID	157		9.700	340.000	-0.500				
GRID	158		8.500	350.000	0.250				
GRID	159		9.700	350.000	0.500				
GRID	160		3.100	15.000	0.				
GRID	161		4.300	15.000	0.				
GRID	162		5.200	15.000	0.				
GRID	163		7.100	10.000	0.				
GRID	169		7.100	20.000	0.				
GRID	170		8.500	10.000	-0.250				

S O R T E D   B U L K   D A T A   E C H O

```
.   1  ..    2  ..    3  ..    4  ..    5  ..    6  ..    7  ..    8  ..    9  ..   10
GRID    171                     9.700   10.000  -0.500
GRID    172                     8.500   20.000  0.250
GRID    173                     9.700   20.000  0.500
MAT1    1       30.0E6                  .3      7.4-4
PARAM   G       .02
PQUAD2  2       1       .25
PQUAD2  3       1       .125
PTRIA2  1       1       .25
RLOAD1  1       1                               100
SPC1    30      6       1       THRU    163
SPC1    30      6       169     THRU    173
SPC1    30      123456  1       10      24      38      52      66
SPC1    30      123456  80      94      108     122     136     150
TABLED1 100                                                             &TBD1
&TBD1   0.0     1.0     1000.0  1.0     ENDT
ENDDATA
```

EXAMPLE 2

A. Description

This example uses the forced vibration capability with cyclic symmetry. The user input/output data for loads, displacements, stresses, etc., pertain to the physical representation of the various segments of the bladed disc. The frequency-dependent applied loads correspond to k = 2, and hence the solution loops on the circumferential harmonic index k are restricted to k = 2 only via parameters KMIN and KMAX.

B. Input

1. Parameters:

In addition to general input parameters,

CYCIO = +1 physical cyclic input/output data
KMIN = 2 minimum circumferential harmonic index
KMAX = 2 maximum circumferential harmonic index
NSEGS = 12 number of rotationally cyclic segments
RPS = 0.0 rotational speed
GKAD = FREQRESP } Specify the form in which the damping parameters
LGKAD = +1 } are used.

2. Constraints:

Same as general input constraints.

3. Loads:

$$P^n(f) = A(f) \cos \left(\overline{n-1} \cdot \textcircled{2} \cdot \frac{2\pi}{\textcircled{12}}\right) ,$$

where n is the segment number,
(2) represents k = 2,
(12) represents the total number of segments in the bladed disc.
P is specified using RLOADi bulk data cards.

C. Results

Displacement and stress output results for selected grid points and elements are presented in Figures 7 through 10. Agreement between results of Figures 7-8 and Figure 4, Figure 9 and Figure 5, and Figure 10 and Figure 6 is excellent.

D. Driver Decks and Bulk Data

```
N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O


ID      NASA.EXAMPLE2
APP     DISP
SOL   8
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$                                                                      $
$ BEGINNING OF RF ALTER 8$A - RF 8 / SERIES R (L17.7) / 1-28-82 / M.G. $
$                                                                      $
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$                                                                      $
$ PURPOSE - TO MODIFY THE DIRECT FREQUENCY AND RANDOM RESPONSE RIGID   $
$           FORMAT TO ENABLE THE USER TO PERFORM A FORCED VIBRATION    $
$           RESPONSE ANALYSIS OF ROTATING CYCLIC STRUCTURES.           $
$                                                                      $
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$ EXECUTIVE DECK INPUT -
$
$    1. SOL 8
$    2. R.F. ALTERS
$
$ CASE CONTROL DECK INPUT -
$
$    1. ALL SPC AND MPC CONSTRAINTS MUST BE ABOVE THE SUBCASE LEVEL.
$    2. EITHER FREQUENCY OR TSTEP MUST BE SELECTED AND MUST BE ABOVE
$       THE SUBCASE LEVEL.
$    3. IF SELECTED, FREQUENCY MUST BE USED TO SELECT ONE AND ONLY
$       ONE FREQ, FREQ1 OR FREQ2 CARD FROM THE BULK DATA DECK AND
$       MUST BE DEFINED ABOVE THE SUBCASE LEVEL.
$    4. IF SELECTED, TSTEP MUST BE USED TO SELECT THE TIME-STEPS TO BE
$       USED FOR LOAD DEFINITION AND MUST BE DEFINED ABOVE THE SUBCASE
$       LEVEL.
$    5. DIRECT INPUT MATRICES ARE NOT ALLOWED.
$    6. OFREQUENCY MUST NOT BE USED.
$    7. A SEPARATE GROUP OF SUBCASES MUST BE DEFINED FOR EACH SYMMETRIC
$       SEGMENT.
$    8. DLOAD MUST BE USED TO DEFINE A FREQUENCY OR TIME-DEPENDENT
$       LOADING CONDITION FOR EACH SUBCASE.
$       FOR FREQUENCY-DEPENDENT LOADS, SUBCASES WITHOUT LOADS NEED NOT
$       REFER TO A DLOAD CARD.
$       FOR TIME-DEPENDENT LOADS, SUBCASES WITHOUT LOADS MUST REFER TO
$       A DLOAD CARD THAT GENERATES A NULL LOAD.
$    9. AN ALTERNATE LOADING METHOD IS TO DEFINE A SEPARATE GROUP OF
$       SUBCASES FOR EACH HARMONIC INDEX, K. THE PARAMETER CYCIO IS
$       INCLUDED AND THE LOAD COMPONENTS FOR EACH INDEX ARE DEFINED
$       DIRECTLY WITHIN EACH GROUP FOR THE VARIOUS LOADING CONDITIONS.
$
$ BULK DATA DECK INPUT -
$
```

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```
$     1. SUPORT BULK DATA CARDS ARE NOT ALLOWED.
$     2. EPOINT BULK DATA CARDS ARE NOT ALLOWED.
$     3. SPOINT BULK DATA CARDS ARE NOT ALLOWED.
$     4. CYJOIN BULK DATA CARDS ARE REQUIRED.
$     5. IF A TSTEP CARD IS USED THEN IT MUST NOT BE CONTINUED SINCE
$        ONLY ONE UNIFORM TIME STEP INTERVAL MUST BE SPECIFIED.
$        THE SKIP FACTOR FOR OUTPUT, NO. ON THE TSTEP CARD MUST BE 1.
$     6. PARAMETERS USED ARE -
$
$        A. NSEGS     - REQUIRED - THE INTEGER VALUE OF THIS PARAMETER
$                       IS THE NUMBER OF IDENTICAL SEGMENTS IN THE
$                       STRUCTURAL MODEL.
$        B. CYCIO     - REQUIRED - THE INTEGER VALUE OF THIS PARAMETER
$                       SPECIFIES THE FORM OF THE INPUT AND OUTPUT DATA.
$                       A VALUE OF &1 IS USED TO SPECIFY PHYSICAL SEGMENT
$                       REPRESENTATION. A VALUE OF -1 IS USED TO SPECIFY
$                       CYCLIC TRANSFORMATION REPRESENTATION. THERE IS NO
$                       DEFAULT, A VALUE MUST BE INPUT.
$        C. CYCSEQ    - FIXED    - THE INTEGER VALUE OF THIS PARAMETER
$                       SPECIFIES THE PROCEDURE FOR SEQUENCING THE
$                       EQUATIONS IN THE SOLUTION SET. THE VALUE OF THIS
$                       PARAMETER HAS BEEN SET TO -1 TO SPECIFY
$                       ALTERNATING COSINE AND SINE TERMS.
$        D. CTYPE     - FIXED    - THE BCD VALUE OF THIS PARAMETER
$                       DEFINES THE TYPE OF CYCLIC SYMMETRY. THE VALUE
$                       OF THIS PARAMETER HAS BEEN SET TO -ROT- FOR
$                       ROTATIONAL SYMMETRY.
$        E. KMAX      - REQUIRED - THE INTEGER VALUE OF THIS PARAMETER
$                       SPECIFIES THE MAXIMUM VALUE OF THE HARMONIC
$                       INDEX. THERE IS NO DEFAULT FOR THIS PARAMETER.
$                       THE MAXIMUM VALUE THAT CAN BE SPECIFIED IS NSEGS/2
$        F. KMIN      - OPTIONAL - THE INTEGER VALUE OF THIS PARAMETER
$                       SPECIFIES THE MINIMUM VALUE OF THE HARMONIC
$                       INDEX TO BE USED IN THE SOLUTION LOOP. KMIN CAN
$                       EQUAL KMAX. THE DEFAULT VALUE IS 0.
$        G. LMAX      - OPTIONAL - THE INTEGER VALUE OF THIS PARAMETER
$                       SPECIFIES THE MAXIMUM TIME HARMONIC INDEX. THE
$                       DEFAULT VALUE IS NTSTEPS/2, WHERE NTSTEPS EQUALS
$                       N (FROM TSTEP CARD) PLUS 2.
$        H. NLOAD     - FIXED    - THE INTEGER VALUE OF THIS PARAMETER
$                       IS THE NUMBER OF LOADING CONDITIONS. THE VALUE
$                       OF THIS PARAMETER IS INTERNALLY CALCULATED.
$        I. RPS       - OPTIONAL - THE REAL VALUE OF THIS PARAMETER
$                       DEFINES THE ROTATIONAL SPEED OF THE STRUCTURE
$                       IN REVOLUTIONS PER UNIT TIME. THE DEFAULT VALUE
$                       IS 0.0 .
$        J. BXTID     - OPTIONAL - THE POSITIVE INTEGER VALUES OF THESE
$           BYTID       PARAMETERS DEFINE THE SET IDENTIFICATION NUMBERS
$           BZTID       OF THE TABLED1 BULK DATA CARDS WHICH DEFINE THE
$           BXPTID      COMPONENTS OF THE BASE ACCELERATION VECTOR. THE
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```
$           BYPTID     TABLES REFERED TO BY BXTID, BYTID AND BZTID
$           BZPTID     DEFINE MAGNITUDE(LT-2) AND THE TABLES REFERED TO
$                      BY BXPTID, BYPTID AND BZPTID DEFINE PHASE(DEGREE).
$                      THE DEFAULT VALUES ARE -1 WHICH MEANS THAT THE
$                      RESPECTIVE TERMS ARE IGNORED.
$        K. NOKPRT   - OPTIONAL - AN INTEGER VALUE OF &1 FOR THIS
$                      PARAMETER WILL CAUSE THE CURRENT HARMONIC INDEX,
$                      KINDEX, TO BE PRINTED AT THE TOP OF THE HARMONIC
$                      LOOP. THE DEFAULT VALUE IS &1.
$        L. GRDPNT   - OPTIONAL - A POSITIVE INTEGER VALUE OF THIS
$                      PARAMETER WILL CAUSE THE GRID POINT WEIGHT
$                      GENERATOR TO BE EXECUTED AND THE RESULTING WEIGHT
$                      BALANCE INFORMATION TO BE PRINTED. DEFAULT IS -1.
$        M. WTMASS   - OPTIONAL  - THE TERMS OF THE STRUCTURAL MASS
$                      MATRIX ARE MULTIPLIED BY THE REAL VALUE OF THIS
$                      PARAMETER WHEN THEY ARE GENERATED IN EMG. THE
$                      DEFAULT IS 1.0 .
$        N. COUPMASS - FIXED     - ONLY LUMPED MASS MATRICES MUST BE USED.
$        O. GKAD     - OPTIONAL - THE BCD VALUE OF THIS PARAMETER IS
$                      USED TO TELL THE GKAD MODULE THE DESIRED FORM OF
$                      MATRICES KDD, BDD AND MDD. THE BCD VALUE CAN BE
$                      FREQRESP OR TRANRESP. THE DEFAULT IS TRANRESP.
$                      NOTE - REMEMBER TO DEFINE PARAMETERS G, W3 AND W4.
$                             SEE SECTION 9.3.3 (DIRECT DYNAMIC MATRIX
$                             ASSEMBLY) PAGES 9.3-7 AND 9.3-8 OF THE
$                             NASTRAN THEORETICAL MANUAL.
$        P. LGKAD    - OPTIONAL - THE INTEGER VALUE OF THIS PARAMETER
$                      IS USED IN CONJUNCTION WITH PARAMETER GKAD. IF
$                      GKAD=FREQRESP THEN SET LGKAD=1. IF GKAD=TRANRESP
$                      THEN SET LGKAD=-1. THE DEFAULT VALUE IS -1.
$        Q. G        - OPTIONAL - THE REAL VALUE OF THIS PARAMETER IS
$                      USED AS A UNIFORM STRUCTURAL DAMPING COEFFICIENT
$                      IN THE DIRECT FORMULATION OF DYNAMICS PROBLEMS.
$        R. W3       - OPTIONAL - THE REAL VALUE OF THIS PARAMETER IS
$                      USED AS A PIVOTAL FREQUENCY FOR UNIFORM STRUCTUAL
$                      DAMPING IF PARAMETER GKAD=TRANRESP. IN THIS CASE
$                      W3 IS REQUIRED IF UNIFORMED STRUCTUAL DAMPING IS
$                      DESIRED. THE DEFAULT VALUE IS 0.0 .
$        S. W4       - OPTIONAL - THE REAL VALUE OF THIS PARAMETER IS
$                      USED AS A PIVOTAL FREQUENCY FOR ELEMENT STRUCTUAL
$                      DAMPING IF PARAMETER GKAD=TRANRESP. IN THIS CASE
$                      W4 IS REQUIRED IF STRUCTUAL DAMPING IS DESIRED FOR
$                      ANY OF THE STRUCTUAL ELEMENTS. DEFAULT IS  0.0 .
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$ REMARKS -
$    1. THE ANALYSIS WILL LOOP THRU A RANGE OF THE CYCLIC INDEX,
$       KINDEX = KMIN TO KMAX.
$
```

N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
ALTER 3 $
FILE      UXVF=APPEND/PUT=APPEND/PD=APPEND $
$ PERFORM INITIAL ERROR CHECKS ON NSEGS AND KMAX.
COND      ERRORC1,NSEGS $  IF USER HAS NOT SPECIFIED NSEGS.
COND      ERRORC1,KMAX  $  IF USER HAS NOT SPECIFIED KMAX.
PARAM     //C,N,EQ /V,N,CYCIOERR /V,Y,CYCIO=0 /C,N,0 $
COND      ERRORC1,CYCIOERR  $  IF USER HAS NOT SPECIFIED CYCIO.
PARAM     //C,N,DIV /V,N,NSEG2 /V,Y,NSEGS /C,N,2 $  NSEG2 = NSEGS/2
PARAM     //C,N,SUB /V,N,KMAXERR /V,N,NSEG2 /V,Y,KMAX $
COND      ERRORC1,KMAXERR $  IF KMAX .GT. NSEGS/2
$ SET DEFAULTS FOR PARAMETERS.
PARAM     //C,N,NOP /V,Y,NOKPRT=&1 /V,Y,LGKAD=-1 $
$ CALCULATE OMEGA, 2*OMEGA AND OMEGA**2 FROM RPS. SET DEFAULT RPS.
PARAMR    //C,N,MPY /V,N,OMEGA /V,Y,RPS=0.0 /C,N,6.283185 $
PARAMR    //C,N,MPY /V,N,OMEGA2 /C,N,2.0 /V,N,OMEGA $
PARAMR    //C,N,MPY /V,N,OMEGASQR /V,N,OMEGA /V,N,OMEGA $
$ GENERATE NORPS FLAG IF RPS IS ZERO.
PARAMR    //C,N,EQ //V,Y,RPS /C,N,0.0 ////V,N,NORPS $
$ MAKE SURE COUPLED MASSES HAVE NOT BEEN REQUESTED.
PARAM     //C,N,NOT /V,N,NOLUMP /V,Y,COUPMASS=-1 $
COND      ERRORC2,NOLUMP $
ALTER 21,21 $  ADD SLT TO OUTPUT FOR TRLG.
GP3       GEOM3,EQEXIN,GEOM2 / SLT,GPTT / V,N,NOGRAV $
CHKPNT    SLT,GPTT $
ALTER 23 $
$ SINCE MULTIPLE CONSTRAINTS ARE NOT ALLOWED EXECUTE GP4 NOW SO THAT
$ MORE ERROR CHECKS CAN BE MADE BEFORE ELEMENT GENERATION.
$ ADD YS NEEDED FOR PSF RECOVERY IN SSG2.
PARAM     //C,N,MPY /V,N,NSKIP /C,N,0 /C,N,0 $
GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM/RG,YS,USET,ASET/V,N,LUSET/
          S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,NSKIP/
          S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,AUTOSPC $
PURGE     GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PSF,QPC/SINGLE $
CHKPNT    GM,GMD,RG,GO,GOD,KFS,PSF,QPC,USET,YS $
$ SUPORT BULK DATA IS NOT ALLOWED.
PARAM     //C,N,NOT /V,N,REACDATA /V,N,REACT $
COND      ERRORC3,REACDATA $
$ EXECUTE DPD NOW SO CHECKS CAN BE MADE. ADD TRL TO OUTPUT DATA BLOCKS.
DPD       DYNAMICS,GPL,SIL,USET / GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,
          TRL,,EQDYN / V,N,LUSET/S,N,LUSETD/V,N,NOTFL/S,N,NODLT/
          S,N,NOPSDL/S,N,NOFRL/V,N,NONLFT/S,N,NOTRL/V,N,NOEED/C,N,/
          S,N,NOUE $
$ MUST HAVE EITHER FREQ OR TSTEP BULK DATA.
PARAM     //C,N,AND/V,N,FTERR /V,N,NOFRL /V,N,NOTRL $
COND      ERRORC5,FTERR $  NO FREQ OR TSTEP BULK DATA.
$ ONLY FREQUENCY OR TSTEP IS ALLOWED IN THE CASE CONTROL
PARAML    CASECC //C,N,DTI /C,N,1 /C,N,14 //V,N,FREQSET $
PARAML    CASECC //C,N,DTI /C,N,1 /C,N,38 //V,N,TIMESET $
PARAM     //C,N,MPY /V,N,FREQTIME /V,N,FREQSET /V,N,TIMESET $
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PARAM    //C,N,NOT /V,N,FTERR1 /V,N,FREQTIME $
PARAM    //C,N,LE /V,N,NOFREQ /V,N,FREQSET /C,N,0 $
PARAM    //C,N,LE /V,N,NOTIME /V,N,TIMESET /C,N,0 $
COND     ERRORC6,FTERR1 $  BOTH FREQ AND TSTEP IN CASE CONTROL DECK.
$ EPOINT BULK DATA NOT ALLOWED
PARAM    //C,N,NOT /V,N,EXTRAPTS /V,N,NOUE $
COND     ERRORC4,EXTRAPTS $
$ GENERATE DATA FOR CYCT2 MODULE.
GPCYC    GEOM4,EQDYN,USETD /CYCDD /V,N,CTYPE=ROT /S,N,NOGO $
COND     ERRORC1,NOGO $
CHKPNT   CYCDD $
ALTER 32 $
$ PRE-PURGE DATA BLOCKS THAT WILL NOT BE GENERATED
PARAM    //C,N,OR /V,N,NOBM1 /V,N,NOMGG /V,N,NORPS $
PURGE    B1GG,M1GG /NOBM1 $
PURGE    M2GG,M2BASEXG /NOMGG $
ALTER 35 $
$ GENERATE DATA BLOCKS FRLX, B1GG, M1GG, M2GG AND BASEGX.
$ GENERATE PARAMETERS FKMAX AND NOBASEX.
DUMMOD1  CASECC,BGPDT,CSTM,DIT,FRL,MGG,, / FRLX,B1GG,M1GG,
         M2GG,BASEXG,PDZERO,, /V,N,NOMGG/V,Y,CYCIC/V,Y,NSEGS/
         V,Y,KMAX/S,N,FKMAX/V,Y,BXTID=-1/V,Y,BXPTID=-1/
         V,Y,BYTID=-1/V,Y,BYPTID=-1/V,Y,BZTID=-1/
         V,Y,BZPTID=-1/S,N,NOBASEX/V,N,NOFREQ/V,N,OMEGA  $
PARAML   FRLX //C,N,PRESENCE ////V,N,NOFRLX $
COND     LBLFRLX,NOFRLX $
EQUIV    FRLX,FRL $
LABEL    LBLFRLX $
CHKPNT   FRL,B1GG,M1GG,M2GG,BASEXG $
ALTER 42 $
PARAM    //C,N,ADD /V,N,NOBGG /V,N,NOBM1 /C,N,0 $  RESET NOBGG.
ALTER 52 $
$ REDEFINE BGG AND KGG.
COND     LBL11A,NOBM1 $
PARAMR   //C,N,COMPLEX // V,N,OMEGA2 / C,N,0.0 / V,N,CMPLX1 $
PARAMR   //C,N,SUB / V,N,MOMEGASQ / C,N,0.0 / V,N,OMEGASQR $
PARAMR   //C,N,COMPLEX // V,N,MOMEGASQ / C,N,0.0 / V,N,CMPLX2 $
ADD      BGG,B1GG / BGG1 / C,N,(1.0,0.0) / V,N,CMPLX1 $
EQUIV    BGG1,BGG $
ADD      KGG,M1GG / KGG1 / C,N,(1.0,0.0) / V,N,CMPLX2 $
EQUIV    KGG1,KGG $
CHKPNT   BGG,KGG $
LABEL    LBL11A
ALTER 53,55 $ GP4 HAS BEEN MOVED-UP.
ALTER 68,68 $ GPD HAS BEEN MOVED-UP.
ALTER 114 $  PARAM AND EQUIV LOGIC DEPENDING ON LGKAD FOR FREQ OR TRAN.
PARAM    //C,N,AND/V,N,KDEKA/V,N,NOUE/V,N,NOK2PP $
COND     LGKAD1,LGKAD $  BRANCH IN NOT FREQRESP.
ALTER 115 $  SEE ALTER 114 COMMENT.
JUMP     LGKAD2 $
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LABEL    LGKAD1 $
EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/
         KAA,KDD/KDEKA $
CHKPNT   K2PP,M2PP,B2PP,K2DD,M2DD,B2DD,KDD,MDD $
LABEL    LGKAD2 $
ALTER 117,117 $ ADD PARAMETERS GKAD, W3 AND W4 TO GKAD.
GKAD     USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
         GOD,K2DD,M2DD,B2DD/C,Y,GKAD=TRANRESP/C,N,DISP/C,N,DIRECT/
         C,Y,G=0.0/C,Y,W3=0.0/C,Y,W4=0.0/V,N,NOK2PP/V,N,NOM2PP/
         V,N,NOB2PP/V,N,MPCF1/V,N,SINGLE/V,N,OMIT/V,N,NOUE/V,N,NOK4GG/
         V,N,NOBGG/V,N,KDEK2/C,N,-1 $
ALTER 118 $  SEE ALTER 114 COMMENT.
COND     LGKAD3,LGKAD $  BRANCH IF NOT FREGRESP.
ALTER 119 $  SEE ALTER 114 COMMENT.
JUMP     LGKAD4 $
LABEL    LGKAD3 $
EQUIV    B2DD,BDD/NOGPDT/M2DD,MDD/NOSIMP/K2DD,KDD/KDEK2 $
LABEL    LGKAD4 $
ALTER 120,123 $
$ NEW SOLUTION LOGIC
$ GENERATE TIME-DEPENDENT LOADS IF TSTEP WAS REQUESTED IN CASE CONTROL.
COND     LBLTRL1,NOTIME $
$ LOOP THRU ALL SUBCASES FOR TIME-DEPENDENT LOADS.
PARAM    //C,N,MPY /V,N,REPEATT /C,N,1 /C,N,-1 $
PARAM    //C,N,ADD /V,N,APPFLG /C,N,1 /C,N,0 $  INITIALIZE FOR SDR1.
JUMP     TRLGLOOP $
LABEL    TRLGLOOP $
CASE     CASECC,/CASEYY/C,N,TRAN/S,N,REPEATT/S,N,NOLOOP1 $
CHKPNT   CASEYY $
PARAM    //C,N,MPY /V,N,NCOL /C,N,0 /C,N,1 $
TRLG     CASEYY,USETD,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GOD,,EST,MGG/
         ,,PDT1,PD1,,TOL/ V,N,NOSET/S,N,PDEPDO/V,N,NCOL $
SDR1     TRL,PDT1,,,,,,,,, / ,PDT, /V,N,APPFLG/C,N,DYNAMICS $
SDR1     TRL,PD1 ,,,,,,,,, / ,PD  , /V,N,APPFLG/C,N,DYNAMICS $
PARAM    //C,N,ADD /V,N,APPFLG /V,N,APPFLG /C,N,1 $  APPFLG=APPFLG&1.
COND     TRLGDONE,REPEATT $
REPT     TRLGLOOP,100 $
JUMP     ERROR3 $
LABEL    TRLGDONE $
CHKPNT   PDT,PD,TOL $
EQUIV    PD,PDT/PDEPDO $
CHKPNT   PDT $
DUMMOD2  TOL,,,,,,, / FRLZ,FOLZ,REORDER1,REORDER2,,,, /
         V,Y,NSEGS/V,Y,CYCIO/S,Y,LMAX=-1/V,N,FKMAX/
         S,N,FLMAX/S,N,NTSTEPS/S,N,NORC1/S,N,NORC2 $
EQUIV    FRLZ,FRL // FOLZ,FOL $
CHKPNT   FRL,FOL,REORDER1,REORDER2 $
JUMP     LBLFRL2 $
LABEL    LBLTRL1 $
$ GENERATE FREQUENCY-DEPENDENT LOADS IF FREQUENCY WAS SELECTED IN CC.
```

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FRLG      CASEXX,USETD,DLT,FRL,GMD,GOD,DIT, / PPF,PSF,PDF,FOL,PHFDUM /
          C,N,DIRECT/V,N,FREQY/C,N,FREQ $
COND      LBLFRLX1,NOFRLX $  ZERO OUT LOAD COLUMNS IF FRLX WAS GENERATED.
MPYAD     PPF,PDZERO, / PPFX /C,N,0 $
EQUIV     PPFX,PPF $
LABEL     LBLFRLX1 $
$ FORM NEW LOADS.
COND      LBLFRL1,NOBASEX $
MPYAD     M2GG,BASEXG, / M2BASEXG /C,N,0 $
ADD       PPF,M2BASEXG / PPF1 /C,N,(1.0,0.0) /C,N,(-1.0,0.0) $
EQUIV     PPF1,PPF $
COND      LBLBASE1,NOSET $
SSG2      USETD,GMD,YS,KFS,GOD,,PPF / ,PODUM1,PSF1,PDF1 $
EQUIV     PSF1,PSF // PDF1,PDF $
LABEL     LBLBASE1 $
LABEL     LBLFRL1 $
EQUIV     PPF,PDF/NOSET $
CHKPNT    PPF,PSF,PDF,FOL $
$ LOADS ARE FREQUENCY-DEPENDENT
$ PERFORM CYCLIC TRANSFORMATION ON LOADS IF CYCIC=&1.
PARAML    PDF //C,N,TRAILER /C,N,1 /V,N,PDFCOLS $
$ CALCULATE THE NUMBER OF LOADS FOR CYCIC=-1.
PARAM     //C,N,DIV /V,N,NLOAD /V,N,PDFCOLS /V,N,FKMAX $ NLOAD = NF/FKMAX
EQUIV     PDF,PXF/CYCIO $
COND      LBLPDONE,CYCIO $
$ CALCULATE THE NUMBER OF LOADS FOR CYCIO=1.
PARAM     //C,N,DIV /V,N,NLOAD /V,N,PDFCOLS /V,Y,NSEGS $ NLOAD = NF/NSEGS
CYCT1     PDF / PXF,GCYCF1 /V,N,CTYPE /C,N,FORE /V,Y,NSEGS=-1 /
          V,Y,KMAX=-1 / V,N,NLOAD /S,N,NOGO $
COND      ERRORC1,NOGO $
CHKPNT    PXF $
JUMP      LBLPDONE $
LABEL     LBLFRL2 $
$ LOADS ARE TIME-DEPENDENT
PARAM     //C,N,NOT /V,N,NOTCYCIO /V,Y,CYCIO $
$ BRANCH DEPENDING ON VALUE OF CYCIO
COND      LBLTRL2,NOTCYCIO $
$ CYCIO=-1
EQUIV     PDT,PDTRZ1/NORO1 $
COND      LBLRO1A,NORO1 $
MPYAD     PDT,REORDER1, / PDTRZ1 / C,N,0 $
LABEL     LBLRO1A $
CYCT1     PDTRZ1 / PXTRZ1,GCYCF2 /V,N,CTYPE/C,N,FORE/V,N,NTSTEPS/
          V,Y,LMAX/V,N,FKMAX/S,N,NOGO $
COND      ERRORC1,NOGO $
CHKPNT    PXTRZ1 $
EQUIV     PXTRZ1,PXFZ1/NORO2 $
COND      LBLRO2A,NORO2 $
MPYAD     PXTRZ1,REORDER2, / PXFZ1 /C,N,0 $
LABEL     LBLRO2A $
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EQUIV     PXFZ1,PXF1 $
CHKPNT    PXF1 $
JUMP      LBLTRL3 $
LABEL     LBLTRL2 $
$ CYC10 = &1
MPYAD     PDT,REORDER1, / PDTRZ2 / C,N,0 $
CYCT1     PDTRZ2 /PXTRZ2,GCYCF3 /V,N,CTYPE/C,N,FORE/V,N,NTSTEPS/V,Y,LMAX/
               V,Y,NSEGS/S,N,NOGO $
COND      ERRORC1,NOGO $
CHKPNT    PXTRZ2 $
EQUIV     PXTRZ2,PXTR2/NORO2 $
COND      LBLRO2B,NORO2 $
MPYAD     PXTRZ2,REORDER2, / PXTR2 /C,N,0 $
LABEL     LBLRO2B $
CYCT1     PXTR2 / PXFZ2,GCYCF4 / V,N,CTYPE/C,N,FORE/V,Y,NSEGS/V,Y,KMAX/
                V,N,FLMAX/S,N,NOGO $
COND      ERRORC1,NOGO $
EQUIV     PXFZ2,PXF1 $
CHKPNT    PXF1 $
LABEL     LBLTRL3 $
$ TIME-DEPENDENT LOADS ARE REAL. MAKE LOADS COMPLEX TO CORRESPOND
$ TO FREQUENCY DEPENDENT LOADS. ALSO SDR2 EXPECTS LOADS TO BE COMPLEX
$ IN FREQRESP TYPE PROBLEMS.
COPY      PXF1 / PXF2  $  CONVERT REAL PXF1 TO COMPLEX PXF.
ADD       PXF1,PXF2 / PXF / C,N,(0.5,1.0) / C,N,(0.5,-1.0) $
$ DEFINE NLOAD FOR CYCT2.
PARAM     //C,N,ADD /V,N,NLOAD /V,N,FLMAX /C,N,0 $  NLOAD = FLMAX
LABEL     LBLPDONE $
PARAM     //C,N,ADD /V,N,KINDEX /V,Y,KMIN=0 /C,N,0 $  INTITIALIZE KINDEX.
$
$ INITIALIZE UXVF IF KMIN IS NOT ZERO.
$
PARAM     //C,N,ADD /V,N,KMINL /V,Y,KMIN /C,N,-1 $
COND      NOKMINL,KMINL $
PARAM     //C,N,ADD /V,N,KMINV /C,N,0 /C,N,0 $
JUMP      KMINLOOP $
LABEL     KMINLOOP $
CYCT2     CYCDD,,,PXF,, /,,PKFZ,, / C,N,FORE/V,Y,NSEGS/
          V,N,KMINV/V,N,CYCSEQ/V,N,NLOAD/S,N,NOGO $
COND      ERRORC1,NOGO $
ADD       PKFZ, / UKVFZ / C,N,(0.0,0.0) $
CYCT2     CYCDD,,,UKVFZ,, /,,UXVF,, / C,N,BACK/V,Y,NSEGS/
          V,N,KMINV/V,N,CYCSEQ/V,N,NLOAD/S,N,NOGO $
COND      ERRORC1,NOGO $
PARAM     //C,N,ADD /V,N,KMINV /V,N,KMINV /C,N,1 $
REPT      KMINLOOP,KMINL $
LABEL     NOKMINL $
$
JUMP      TOPCYC $
LABEL     TOPCYC $  LOOP ON KINDEX
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CUND      NOKPRT,NOKPRT $
PRTPARM   //C,N,0 /C,N,KINDEX $
LABEL     NOKPRT $
CYCT2     CYCDD,KDD,MDD,,, /KKKF,MKKF,,, /C,N,FORE/V,Y,NSEGS /
          V,N,KINDEX/V,N,CYCSEQ=-1/V,N,NLOAD/S,N,NOGO $
COND      ERRORC1,NOGO $
CHKPNT    KKKF,MKKF $
PARAM     //C,N,SYST //C,N,58 /C,N,2 $  METHOD 3T IN CYCT2 PRODUCES
$                                       UNDERFLOWS FOR PXF. USE METHOD 2.
CYCT2     CYCDD,BDD,,PXF,, /BKKF,,PKF,, / C,N,FORE/V,Y,NSEGS/
          V,N,KINDEX/V,N,CYCSEQ/V,N,NLOAD/S,N,NOGO $
PARAM     //C,N,SYST //C,N,58 /C,N,0 $  RESET MPYAD METHOD CONTROL.
COND      ERRORC1,NOGO $
CHKPNT    BKKF,PKF $
$ SOLUTION
FRRD2     KKKF,BKKF,MKKF,,PKF,FOL / UKVF /C,N,0.0/C,N,0.0/C,N,-1.0 $
CHKPNT    UKVF $
CYCT2     CYCDD,,,UKVF,, /,,UXVF,, /C,N,BACK/V,Y,NSEGS/V,N,KINDEX/
          V,N,CYCSEQ/V,N,NLOAD/S,N,NOGO $
COND      ERRORC1,NOGO $
CHKPNT    UXVF $
PARAM     //C,N,ADD /V,N,KINDEX/V,N,KINDEX/C,N,1 $  KINDEX = KINDEX & 1
PARAM     //C,N,SUB /V,N,DONE / V,Y,KMAX / V,N,KINDEX $
COND      LCYC2,DONE $  IF KINDEX .GT. KMAX THEN EXIT
REPT      TOPCYC,100 $
JUMP      ERROR3 $
LABEL     LCYC2 $
EQUIV     UXVF,UDVF / CYCIO $
CHKPNT    UDVF $
COND      LCYC3,CYCIO $  IF CYCIO .GE. 0 THEN TRANSFORM TO PHYSICAL.
CYCT1     UXVF / UDVF,GCYCB1 / V,N,CTYPE/C,N,BACK/V,Y,NSEGS/V,Y,KMAX/
          V,N,NLOAD $
CHKPNT    UDVF $
LABEL     LCYC3 $
COND      LBLTRL4,NOTIME $
EQUIV     PXF,PDF2 / CYCIO $
COND      LCYC4,CYCIO $  IF CYCIO .GE. 0 THEN TRANSFORM TO PHYSICAL.
CYCT1     PXF / PDF2,GCYCB2 / V,N,CTYPE/C,N,BACK/V,Y,NSEGS/V,Y,KMAX/
          V,N,NLOAD $
LABEL     LCYC4 $
$ IF LOADS WERE TIME-DEPENDENT THEN RECOVER PPF AND PSF FROM PXF.
SDR1      USETD,,PDF2,,,GOD,GMD,,,, / PPFZ,, /C,N,1 /C,N,DYNAMICS $
SSG2      USETD,GMD,YS,KFS,GOD,,PPFZ / ,PODUM,PSFZ,PLDUM $
EQUIV     PPFZ,PPF // PSFZ,PSF $
CHKPNT    PPF,PSF $
LABEL     LBLTRL4 $
ALTER 124,124 $  USE FOL INSTEAD OF PPF TO GET OUTPUT FREQUENCY LIST.
VDR       CASEXX,EQDYN,USETD,UDVF,FOL,XYCDB,/OUDVC1,/C,N,FREQRESP/C,N,
          DIRECT/S,N,NOSORT2/S,N,NOD/S,N,NOP/C,N,0 $
ALTER 140,140 $  USE FOL INSTEAD OF PPF TO GET OUTPUT FREQUENCY LIST.
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SDR2      CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,FLL,QPC,UPVC,EST,XYCDB,
          PPF/OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,PUPVC1/C,N,FREQRESP/
          S,N,NOSORT2 $
ALTER 160  $  ADD LABEL FOR ERROR3.
LABEL     ERROR3 $
ALTER 163,166 $  REMOVE ERROR1 AND ERROR2.
ALTER 168 $ FORCED VIBRATION ERRORS
LABEL     ERRORC1 $  CHECK NSEGS, KMAX AND OTHER CYCLIC DATA.
PRTPARM   //C,N,-7 /C,N,CYCSTATICS $
LABEL     ERRORC2 $  COUPLED MASS NOT ALLOWED.
PRTPARM   //C,N,0 /C,Y,COUPMASS $
JUMP      FINIS $
LABEL     ERRORC3 $  SUPORT BULK DATA NOT ALLOWED.
PRTPARM   //C,N,-6 /C,N,CYCSTATICS $
LABEL     ERRORC4 $  EPOINT BULK DATA NOT ALLOWED.
PRTPARM   //C,N,0 /C,N,NOUE $
JUMP      FINIS $
LABEL     ERRORC5 $  NEITHER FREQ OR TSTEP WERE IN BULK DATA DECK.
PRTPARM   //C,N,0 /C,N,NOFRL $
PRTPARM   //C,N,0 /C,N,NOTRL $
JUMP      FINIS $
LABEL     ERRORC6 $  BOTH FREQ AND TSTEP WERE SELECTED IN CASE CONTROL.
PRTPARM   //C,N,0 /C,N,NOFREQ $
PRTPARM   //C,N,0 /C,N,NOTIME $
JUMP      FINIS $
ENDALTER
TIME      5   $ IBM 370/3031
DIAG      14,21
CEND
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                         C A S E   C O N T R O L   D E C K   E C H O
CARD
COUNT
  1      $
  2      TITLE = FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
  3      SUBTITLE = BLADED DISC EXAMPLE 2 (CYC MODEL(FREQ LOADS,PHYSICAL I/O)
  4      $
  5        SPC    = 30
  6        FREQ   = 1
  7      OUTPUT
  8        SET 1 = 8,16,18
  9        DLOAD = 1
 10        DISP(SORT2,PHASE)    = ALL
 11        STRESS(SORT2,PHASE) = ALL
 12          SUBCASE 1
 13            LABEL = SEGMENT 1
 14            DLOAD = 1    $ FREQ DEPENDENT LOADS
 15          SUBCASE 2
 16            LABEL = SEGMENT 2
 17            DLOAD = 2    $ FREQ DEPENDENT LOADS
 18          SUBCASE 3
 19            LABEL = SEGMENT 3
 20            DLOAD = 3    $ FREQ DEPENDENT LOADS
 21          SUBCASE 4
 22            LABEL = SEGMENT 4
 23            DLOAD = 4    $ FREQ DEPENDENT LOADS
 24          SUBCASE 5
 25            LABEL = SEGMENT 5
 26            DLOAD = 5    $ FREQ DEPENDENT LOADS
 27          SUBCASE 6
 28            LABEL = SEGMENT 6
 29            DLOAD = 6    $ FREQ DEPENDENT LOADS
 30          SUBCASE 7
 31            LABEL = SEGMENT 7
 32            DLOAD = 7    $ FREQ DEPENDENT LOADS
 33          SUBCASE 8
 34            LABEL = SEGMENT 8
 35            DLOAD = 8    $ FREQ DEPENDENT LOADS
 36          SUBCASE 9
 37            LABEL = SEGMENT 9
 38            DLOAD = 9    $ FREQ DEPENDENT LOADS
 39          SUBCASE 10
 40            LABEL = SEGMENT 10
 41            DLOAD = 10   $ FREQ DEPENDENT LOADS
 42          SUBCASE 11
 43            LABEL = SEGMENT 11
 44            DLOAD = 11   $ FREQ DEPENDENT LOADS
 45          SUBCASE 12
 46            LABEL = SEGMENT 12
 47            DLOAD = 12   $ FREQ DEPENDENT LOADS
 48      OUTPUT(XYPLOT)
 49        PLOTTER NASTPLT, MODEL D,0
 50        XPAPER = 8.0
```

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                              C A S E   C O N T R O L   D E C K   E C H O
CARD
COUNT
51            YPAPER = 10.5
52            XAXIS = YES
53            YAXIS = YES
54            XGRID LINES = YES
55            YGRID LINES = YES
56            CURVELINESYMBOL = 1
57            YLOG = YES
58            XTITLE =                             FREQUENCY (HERTZ)
59            YTITLE =           GRID POINT DISPLACEMENTS ( MAGNITUDE,INCH )
60            TCURVE = 14(T3RM),18(T3RM)
61           XYPLOT,XYPRINT DISP RESPONSE 1 /14(T3RM),18(T3RM)
62            TCURVE = 2(T3RM)
63           XYPLOT,XYPRINT DISP RESPONSE 8 /2(T3RM)
64            YTITLE =                   ELEMENT STRESSES ( MAGNITUDE,PSI )
65            TCURVE = 11(3),11(5),11(7),11(10),11(12),11(14)
66           XYPLOT,XYPRINT STRESS RESPONSE 1 /11(3),11(5),11(7),
67                                            11(10),11(12),11(14)
68            TCURVE = 1(3),1(5),1(7),1(10),1(12),1(14)
69           XYPLOT,XYPRINT STRESS RESPONSE 10 /1(3),1(5),1(7),
70                                            1(10),1(12),1(14)
71         BEGIN BULK

*INFORMATION MESSAGE 207, BULK DATA NOT SORTED,XSORT WILL RE-ORDER DECK.
```

ORIGINAL PAGE IS OF POOR QUALITY

S O R T E D   B U L K   D A T A   E C H O

. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
CORD2C	1		.0	.0	.0	1.0	.0	.0	&COR12
&COR12	0.0	1.0	0.0						
CQUAD2	4	2	2	3	7	6			
CQUAD2	5	2	6	7	12	11			
CQUAD2	6	2	3	4	8	7			
CQUAD2	7	2	7	8	13	12			
CQUAD2	8	2	4	5	9	8			
CQUAD2	10	2	8	15	14	13			
CQUAD2	11	3	9	16	18	15			
CQUAD2	12	3	16	17	19	18			
CTRIA2	1	1	1	6	10				
CTRIA2	2	1	1	2	6				
CTRIA2	3	1	10	6	11				
CTRIA2	9	1	8	9	15				
CYJOIN	1		1	2	3	4	5		
CYJOIN	2		10	11	12	13	14		
DAREA	1	8	3	-1.0					
DAREA	1	16	3	1.0					
DAREA	1	18	3	1.0					
DAREA	2	8	3	-0.5					
DAREA	2	16	3	.5					
DAREA	2	18	3	.5					
DAREA	3	8	3	.5					
DAREA	3	16	3	-0.5					
DAREA	3	18	3	-0.5					
DAREA	4	8	3	1.0					
DAREA	4	16	3	-1.0					
DAREA	4	18	3	-1.0					
DAREA	5	8	3	.5					
DAREA	5	16	3	-0.5					
DAREA	5	18	3	-0.5					
DAREA	6	8	3	-0.5					
DAREA	6	16	3	.5					
DAREA	6	18	3	.5					
DAREA	7	8	3	-1.0					
DAREA	7	16	3	1.0					
DAREA	7	18	3	1.0					
DAREA	8	8	3	-0.5					
DAREA	8	16	3	.5					
DAREA	8	18	3	.5					
DAREA	9	8	3	.5					
DAREA	9	16	3	-0.5					
DAREA	9	18	3	-0.5					
DAREA	10	8	3	1.0					
DAREA	10	16	3	-1.0					
DAREA	10	18	3	-1.0					
DAREA	11	8	3	.5					
DAREA	11	16	3	-0.5					
DAREA	11	18	3	-0.5					
DAREA	12	8	3	-0.5					

S O R T E D   B U L K   D A T A   E C H O

. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
DAREA	12	16	3	.5					
DAREA	12	18	3	.5					
FREQ	1	1700.0	1750.0	1777.6	1795.7	1823.854	1832.0	1850.1	&FR1
&FR1	1880.0	1920.0							
GRDSET		1				1			
GRID	1		2.0	30.0	.0				
GRID	2		3.1	30.0	.0				
GRID	3		4.3	30.0	.0				
GRID	4		5.2	30.0	.0				
GRID	5		7.1	30.0	.0				
GRID	6		3.1	45.0	.0				
GRID	7		4.3	45.0	.0				
GRID	8		5.2	45.0	.0				
GRID	9		7.1	40.0	.0				
GRID	10		2.0	60.0	.0				
GRID	11		3.1	60.0	.0				
GRID	12		4.3	60.0	.0				
GRID	13		5.2	60.0	.0				
GRID	14		7.1	60.0	.0				
GRID	15		7.1	50.0	.0				
GRID	16		8.5	40.0	-.25				
GRID	17		9.7	40.0	-.50				
GRID	18		8.5	50.0	.25				
GRID	19		9.7	50.0	.50				
MAT1	1	30.0&6		.3	7.4-4				
PARAM	CYCIO	&1							
PARAM	G	.02							
PARAM	GKAD	FREQRESP							
PARAM	KMAX	2							
PARAM	KMIN	2							
PARAM	LGKAD	1							
PARAM	NSEGS	12							
PARAM	RPS	.0							
PQUAD2	2	1	.25						
PQUAD2	3	1	.125						
PTRIA2	1	1	.25						
RLOAD1	1	1			100				
RLOAD1	2	2			100				
RLOAD1	3	3			100				
RLOAD1	4	4			100				
RLOAD1	5	5			100				
RLOAD1	6	6			100				
RLOAD1	7	7			100				
RLOAD1	8	8			100				
RLOAD1	9	9			100				
RLOAD1	10	10			100				
RLOAD1	11	11			100				
RLOAD1	12	12			100				
SPC1	30	6	1	THRU	19				
SPC1	30	123456	1	10					

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S O R T E D   B U L K   D A T A   E C H O

```
.   1  ..  2  ..  3  ..  4  ..  5  ..  6  ..  7  ..  8  ..  9  ..  10  .
TABLED1 100                                                        &TBD1
&TBD1   0.0     1.0     1000.0  1.0     ENDT
ENDDATA
```

EXAMPLE 3

A. Description

This example uses the forced vibration capability with cyclic symmetry. The user input/output data pertain to harmonic representation. Frequency-dependent excitation is provided by both directly applied and base acceleration loads.

B. Input

1. Parameters:

   In addition to general input parameters,

   CYCIO = -1 harmonic cyclic input/output data
   KMIN = 0 minimum circumferential harmonic index
   KMAX = 2 maximum circumferential harmonic index
   NSEGS = 12 number of rotationally cyclic sectors
   RPS = 600.0 revolutions per second
   BXTID, BYTID, BZTID } Refer to TABLEDi bulk data cards to specify
   BXPTID, BYPTID, BZPTID } magnitude and phase of base acceleration components.
   GKAD = FREQRESP } Specify the form in which damping parameters are
   LGKAD = +1 } used.

2. Constraints:

   Same as general input constraints.

3. Loads:

   a) $\overline{P}^{0,2c} = A(f)$ specified on RLOADi bulk data cards.
   b) Base acceleration as shown in Figure 11.

C. Results

Results are shown in Figures 12 through 20.

Figures 12 and 13 present k = 0 results (subcase 1). The excitation consists of axial base acceleration and directly applied loads. The selected frequency band of excitation, 1700-1920 Hz, lies between the second out-of-plane disc bending mode frequency (1577 Hz, k = 0, Table 2) and the first in-plane shear mode frequency (1994 Hz, k = 0, Table 2). Since the excitation is parallel to the axis of rotation, only the former mode responds.

Figures 14 through 18 present k = 1 results (subcases 2 (k = 1c) and 3 (k = 1s)). The excitation is due to lateral base acceleration only. Although the frequency band of input base acceleration is 1700-1920 Hz, the rotation of the bladed disc at 600 Hz (parameter RPS) splits the input bandwidth into two effective bandwidths:

(1700 - 600) = 1100 to (1920 - 600) = 1320 Hz, and
(1700 + 600) = 2300 to (1920 + 600) = 2520 Hz.

The only k = 1 mode in these effective bandwidths is the first torsional mode of the blade with the disc practically stationary (2460 Hz, k = 1, Table 2). This is shown by the out-of-plane displacement magnitudes of grid points 18 (blade) and 8 (disc) respectively (Figures 14 (k = 1c) and 17 (k = 1s)). The corresponding phase responses of these grid points are shown in Figure 16.

Figures 19 and 20 present k = 2 results (subcase 4 (k = 2c)). The excitation consists of directly applied k = 2c loads. The out-of-plane displacement magnitude of grid point 18 (Figure 19) compares well with that obtained in example 2 (Figure 7). Table 3 lists the out-of-plane displacement response of grid point 18 as obtained in examples 2 and 3. The marginal difference in response in example 3 is due to the Coriolis and centripetal acceleration effects at a rotational speed of 600 revolutions per second.

No k = 2s loads are applied in this example (subcase 5).

D. Driver Decks and Bulk Data

N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

```
ID        NASA,EXAMPLE3
APP       DISP
SOL       8
$
$         ALTER PACKAGE AS IN EXAMPLE2
$
TIME      12 $ IBM 370/3031
DIAG      14,21
CEND
```

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C A S E   C O N T R O L   D E C K   E C H O

CARD
COUNT

```
$
TITLE = FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
SUBTITLE = BLADED DISC EXAMPLE 3 (CYC MODEL,FREEBASE ACCN LOAD,HARM I/O)
$
   SPC    = 30
   FREQ   = 1
OUTPUT
   SET 1 = 8,16,18
   SET 2 = 11
   DLOAD = 1
   DISP(SORT2,PHASE)    = 1
   STRESS(SORT2,PHASE) = 2
     SUBCASE 1
        LABEL = KINDEX 0
        DLOAD = 1    $ FREQ DEPENDENT LOADS
$                       $ AXIAL BASE ACCN LOADS VIA PARAM BXTID,BXPTID
     SUBCASE 2
        LABEL = KINDEX 1C
$                       $ LATERAL BASE ACCN LOADS VIA PARAM BYTID
     SUBCASE 3
        LABEL = KINDEX 1S
$                       $ LATERAL BASE ACCN LOADS VIA PARAM BZTID
     SUBCASE 4
        LABEL = KINDEX 2C
        DLOAD = 1    $ FREQ DEPENDENT LOADS
     SUBCASE 5
        LABEL = KINDEX 2S
OUTPUT(XYPLOT)
   PLOTTER NASTPLT, MODEL D,0
   XPAPER = 8.0
   YPAPER = 10.5
   XAXIS = YES
   YAXIS = YES
   XGRID LINES = YES
   YGRID LINES = YES
   CURVELINESYMBOL = 1
   XTITLE =                                FREQUENCY (HERTZ)
   YTITLE =              GRID POINT DISPLACEMENTS ( MAGNITUDE,INCH )
   YLOG = YES
   TCURVE = 8(T3RM),18(T3RM)
  XYPLOT,XYPRINT DISP RESPONSE 1 /8(T3RM),18(T3RM)
  XYPLOT,XYPRINT DISP RESPONSE 2 /8(T3RM),18(T3RM)
  XYPLOT,XYPRINT DISP RESPONSE 3 /8(T3RM),18(T3RM)
  XYPLOT,XYPRINT DISP RESPONSE 4 /8(T3RM),18(T3RM)
   YTITLE =              GRID POINT DISPLACEMENTS ( PHASE,DEGREE )
   YLOG = NO
   TCURVE = 8(T3IP),18(T3IP)
  XYPLOT,XYPRINT DISP RESPONSE 2 /8(T3IP),18(T3IP)
   YTITLE =                        ELEMENT STRESSES ( MAGNITUDE,PSI )
   YLOG = YES
```

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```
                              C A S E   C O N T R O L   D E C K   E C H O
CARD
COUNT
 51          TCURVE = 11(3),11(5),11(7),11(10),11(12),11(14)
 52         XYPLOT,XYPRINT STRESS RESPONSE 1 /11(3),11(5),11(7),
 53                                           11(10),11(12),11(14)
 54         XYPLOT,XYPRINT STRESS RESPONSE 2 /11(3),11(5),11(7),
 55                                           11(10),11(12),11(14)
 56         XYPLOT,XYPRINT STRESS RESPONSE 3 /11(3),11(5),11(7),
 57                                           11(10),11(12),11(14)
 58         XYPLOT,XYPRINT STRESS RESPONSE 4 /11(3),11(5),11(7),
 59                                           11(10),11(12),11(14)
 60       BEGIN BULK

MATION MESSAGE 207, BULK DATA NOT SORTED,XSORT WILL RE-ORDER DECK.
```

S O R T E D   B U L K   D A T A   E C H O

```
.   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
CORD2C  1               .0      .0      .0      1.0     .0      .0      &COR12
&COR12  0.0     1.0     0.0
CQUAD2  4       2       2       3       7       6
CQUAD2  5       2       6       7       12      11
CQUAD2  6       2       3       4       8       7
CQUAD2  7       2       7       8       13      12
CQUAD2  8       2       4       5       9       8
CQUAD2  10      2       8       15      14      13
CQUAD2  11      3       9       16      18      15
CQUAD2  12      3       16      17      19      18
CTRIA2  1       1       1       6       10
CTRIA2  2       1       1       2       6
CTRIA2  3       1       10      6       11
CTRIA2  9       1       8       9       15
CYJOIN  1               1       2       3       4       5
CYJOIN  2               10      11      12      13      14
DAREA   1       8       3       -1.0
DAREA   1       16      3       1.0
DAREA   1       18      3       1.0
FREQ    1       1700.0  1750.0  1777.6  1795.7  1822.8561832.0  1850.1  &FR1
&FR1    1880.0  1920.0
GRDSET          1                                       1
GRID    1               2.0     30.0    .0
GRID    2               3.1     30.0    .0
GRID    3               4.3     30.0    .0
GRID    4               5.2     30.0    .0
GRID    5               7.1     30.0    .0
GRID    6               3.1     45.0    .0
GRID    7               4.3     45.0    .0
GRID    8               5.2     45.0    .0
GRID    9               7.1     40.0    .0
GRID    10              2.0     60.0    .0
GRID    11              3.1     60.0    .0
GRID    12              4.3     60.0    .0
GRID    13              5.2     60.0    .0
GRID    14              7.1     60.0    .0
GRID    15              7.1     50.0    .0
GRID    16              8.5     40.0    -.25
GRID    17              9.7     40.0    -.50
GRID    18              8.5     50.0    .25
GRID    19              9.7     50.0    .50
MAT1    1       30.0E6          .3      7.4-4
PARAM   BXPTID  9002
PARAM   BXTID   9001
PARAM   BYTID   9003
PARAM   BZTID   9004
PARAM   CYCIO   -1
PARAM   G       .02
PARAM   GKAD    FREQRESP
PARAM   KMAX    2
```

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S O R T E D   B U L K   D A T A   E C H O

```
.   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
PARAM   KMIN    0
PARAM   LGKAD   1
PARAM   NSEGS   12
PARAM   RPS     600.0
PQUAD2  2       1       .25
PQUAD2  3       1       .125
PTRIA2  1       1       .25
RLOAD1  1       1                               100
SPC1    30      6       1       THRU    19
SPC1    30      123456  1       10
TABLED1 100                                                             &TBD1
&TBD1   0.0     1.0     1000.0  1.0     ENDT
TABLED1 9001                                                            &TAB11
&TAB11  1000.   0.0     2000.0  1000.0  ENDT
TABLED1 9002                                                            &TAB21
&TAB21  1000.   -180.   2000.0  0.0     ENDT
TABLED1 9003                                                            &TAB31
&TAB31  1000.   1000.0  2000.0  1000.0  ENDT
TABLED1 9004                                                            &TAB41
&TAB41  1000.   500.0   2000.0  500.0   ENDT
ENDDATA
```

EXAMPLE 4

A. Description

This example uses the forced vibration capability with cyclic symmetry. The user input/output pertains to physical representation. Periodic loads are specified as functions of time on the segments of the bladed disc corresponding to k = 2. For clarity of illustration only, sinusoidal loads of varying amplitudes at a frequency of 1814 Hz are specified. The Fourier decomposition of these sine functions obviously contains contributions from first harmonic alone (ℓ = 1)-- the parameter LMAX accordingly has been set at 1 (ℓ = 0, 1c, 1s).

B. Input

1. Parameters:

In addition to general input parameters,

CYCIO = +1 physical cyclic input/output data
KMIN = 2 minimum circumferential harmonic index
KMAX = 2 maximum circumferential harmonic index
LMAX = 1 maximum harmonic in the Fourier decomposition of periodic, time-dependent loads,
NSEGS = 12 number of rotationally cyclic sectors
RPS = 600.0 revolutions per second
GKAD = FREQRESP, LGKAD = +1 } Specify the form in which the damping parameters are used.

2. Constraints:

Same as general input constraints.

3. Loads:

$$P^n(t) = A(t) \cos \left(\overline{n-1} \cdot \textcircled{2} \cdot \frac{2\pi}{\textcircled{12}}\right) ,$$

where n is the segment number,
(2) represents k = 2,
(12) represents the total number of segments in the bladed disc,
A(t) = A·sin (2π·1814·t).
P is specified on TLOADi bulk data cards.

C. Results

Results are presented in Table 4 and are in good agreement with those from example 3.

D. Driver Decks and Bulk Data

N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

```
ID          NASA,EXAMPLE4
APP         DISP
SOL         8
$
$           ALTER PACKAGE AS IN EXAMPLE2
$
TIME        4 $ IBM 370/3031
DIAG        8,14,21
CEND
```

ORIGINAL PAGE IS
OF POOR QUALITY

C A S E   C O N T R O L   D E C K   E C H O

```
CARD
COUNT
  1      $
  2      TITLE = FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
  3      SUBTITLE = BLADED DISC EXAMPLE 4  (CYC MODEL,TIME DEP. LOAD,PHYS I/O)
  4      $
  5         SPC    = 30
  6         TSTEP  = 1
  7      OUTPUT
  8         SET 1 = 8,16,10
  9         SET 2 = 11
 10         DLOAD = 1
 11         DISP(SORT2,REAL)   = 1
 12         STRESS(SORT2,REAL) = 2
 13            SUBCASE 1
 14               LABEL = SEGMENT 1
 15               DLOAD = 1    $ TIME DEPENDENT LOADS
 16            SUBCASE 2
 17               LABEL = SEGMENT 2
 18               DLOAD = 2    $ TIME DEPENDENT LOADS
 19            SUBCASE 3
 20               LABEL = SEGMENT 3
 21               DLOAD = 3    $ TIME DEPENDENT LOADS
 22            SUBCASE 4
 23               LABEL = SEGMENT 4
 24               DLOAD = 4    $ TIME DEPENDENT LOADS
 25            SUBCASE 5
 26               LABEL = SEGMENT 5
 27               DLOAD = 5    $ TIME DEPENDENT LOADS
 28            SUBCASE 6
 29               LABEL = SEGMENT 6
 30               DLOAD = 6    $ TIME DEPENDENT LOADS
 31            SUBCASE 7
 32               LABEL = SEGMENT 7
 33               DLOAD = 7    $ TIME DEPENDENT LOADS
 34            SUBCASE 8
 35               LABEL = SEGMENT 8
 36               DLOAD = 8    $ TIME DEPENDENT LOADS
 37            SUBCASE 9
 38               LABEL = SEGMENT 9
 39               DLOAD = 9    $ TIME DEPENDENT LOADS
 40            SUBCASE 10
 41               LABEL = SEGMENT 10
 42               DLOAD = 10   $ TIME DEPENDENT LOADS
 43            SUBCASE 11
 44               LABEL = SEGMENT 11
 45               DLOAD = 11   $ TIME DEPENDENT LOADS
 46            SUBCASE 12
 47               LABEL = SEGMENT 12
 48               DLOAD = 12   $ TIME DEPENDENT LOADS
 49      BEGIN BULK

INFORMATION MESSAGE 207, BULK DATA NOT SORTED,XSORT WILL RE-ORDER DECK.
```

S O R T E D   B U L K   D A T A   E C H O

. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
CORD2C	1		.0	.0	.0	1.0	.0	.0	&COR12
&COR12	0.0	1.0	0.0						
CQUAD2	4	2	2	3	7	6			
CQUAD2	5	2	6	7	12	11			
CQUAD2	6	2	3	4	8	7			
CQUAD2	7	2	7	8	13	12			
CQUAD2	8	2	4	5	9	8			
CQUAD2	10	2	8	15	14	13			
CQUAD2	11	3	9	16	18	15			
CQUAD2	12	3	16	17	19	18			
CTRIA2	1	1	1	6	10				
CTRIA2	2	1	1	2	6				
CTRIA2	3	1	10	6	11				
CTRIA2	9	1	8	9	15				
CYJOIN	1		1	2	3	4	5		
CYJOIN	2		10	11	12	13	14		
DAREA	1	8	3	-1.0					
DAREA	1	16	3	1.0					
DAREA	1	18	3	1.0					
DAREA	2	8	3	-0.5					
DAREA	2	16	3	.5					
DAREA	2	18	3	.5					
DAREA	3	8	3	.5					
DAREA	3	16	3	-0.5					
DAREA	3	18	3	-0.5					
DAREA	4	8	3	1.0					
DAREA	4	16	3	-1.0					
DAREA	4	18	3	-1.0					
DAREA	5	8	3	.5					
DAREA	5	16	3	-0.5					
DAREA	5	18	3	-0.5					
DAREA	6	8	3	-0.5					
DAREA	6	16	3	.5					
DAREA	6	18	3	.5					
DAREA	7	8	3	-1.0					
DAREA	7	16	3	1.0					
DAREA	7	18	3	1.0					
DAREA	8	8	3	-0.5					
DAREA	8	16	3	.5					
DAREA	8	18	3	.5					
DAREA	9	8	3	.5					
DAREA	9	16	3	-0.5					
DAREA	9	18	3	-0.5					
DAREA	10	8	3	1.0					
DAREA	10	16	3	-1.0					
DAREA	10	18	3	-1.0					
DAREA	11	8	3	.5					
DAREA	11	16	3	-0.5					
DAREA	11	18	3	-0.5					
DAREA	12	8	3	-0.5					

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S O R T E D   B U L K   D A T A   E C H O

. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
DAREA	12	16	3	.5					
DAREA	12	18	3	.5					
GRDSET		1				1			
GRID	1		2.0	30.0	.0				
GRID	2		3.1	30.0	.0				
GRID	3		4.3	30.0	.0				
GRID	4		5.2	30.0	.0				
GRID	5		7.1	30.0	.0				
GRID	6		3.1	45.0	.0				
GRID	7		4.3	45.0	.0				
GRID	8		5.2	45.0	.0				
GRID	9		7.1	40.0	.0				
GRID	10		2.0	60.0	.0				
GRID	11		3.1	60.0	.0				
GRID	12		4.3	60.0	.0				
GRID	13		5.2	60.0	.0				
GRID	14		7.1	60.0	.0				
GRID	15		7.1	50.0	.0				
GRID	16		8.5	40.0	-.25				
GRID	17		9.7	40.0	-.50				
GRID	18		8.5	50.0	.25				
GRID	19		9.7	50.0	.50				
MAT1	1	30.0E6		.3	7.4-4				
PARAM	CYCIO	E1							
PARAM	G	.02							
PARAM	GKAD	FREQRESP							
PARAM	KMAX	2							
PARAM	KMIN	2							
PARAM	LGKAD	1							
PARAM	LMAX	1							
PARAM	NSEGS	12							
PARAM	RPS	600.0							
PQLAD2	2	1	.25						
PQLAD2	3	1	.125						
RTAIL2	1	1	.25						
SPC1	30	6	1	THRU	19				
SPC1	30	123456	1	10					
TLOAD2	1	1			.0	5.5131-41813.854-90.0			
TLOAD2	2	2			.0	5.5131-41813.854-90.0			
TLOAD2	3	3			.0	5.5131-41813.854-90.0			
TLOAD2	4	4			.0	5.5131-41813.854-90.0			
TLOAD2	5	5			.0	5.5131-41813.854-90.0			
TLOAD2	6	6			.0	5.5131-41813.854-90.0			
TLOAD2	7	7			.0	5.5131-41813.854-90.0			
TLOAD2	8	8			.0	5.5131-41813.854-90.0			
TLOAD2	9	9			.0	5.5131-41813.854-90.0			
TLOAD2	10	10			.0	5.5131-41813.854-90.0			
TLOAD2	11	11			.0	5.5131-41813.854-90.0			
TLOAD2	12	12			.0	5.5131-41813.854-90.0			
TSTEP	1	10	4.5943-51						

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S O R T E D   B U L K   D A T A   E C H O

. 1 .. 2 .. 3 .. 4 .. 5 .. 6 .. 7 .. 8 .. 9 .. 10 .

ENDDATA

EXAMPLE 5

A. Description

This example uses the forced vibration capability with cyclic symmetry. The user input/output pertains to harmonic representation. Periodic loads are specified as functions of time for the circumferential harmonic index k = 2. For clarity of illustration only, sinusoidal loads are selected.

B. Input

1. Parameters:

   In addition to general input parameters,

   CYCIO = -1 harmonic cyclic input/output data
   KMIN = 2 minimum circumferential harmonic index
   KMAX = 2 maximum circumferential harmonic index
   LMAX = 1 maximum harmonic in the Fourier decomposition of periodic, time-dependent loads.
   NSEGS = 12 number of rotationally cyclic sectors
   RPS = 600.0 revolutions per second
   GKAD = FREQRESP } Specify the form in which the damping parameters
   LGKAD = +1 } are used.

2. Constraints:

   Same as general input constraints.

3. Loads:

$$\overline{P}^{2c}(t) = A \cdot \sin(2\pi \cdot 1814 \cdot t) ,$$

   specified on TLOADi bulk data cards.

C. Results

Results are presented in Table 4 and agree well with those from example 3.

D. Driver Decks and Bulk Data

N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

```
ID        NASA,EXAMPLE5
APP       DISP
SOL       8
$
$         ALTER PACKAGE AS IN EXAMPLE2
$
TIME      3 $ IBM 370/3031
DIAG      8,14,21
CEND
```

```
                         C A S E    C O N T R O L    D E C K   E C H O
 CARD
 COUNT
   1      $
   2      TITLE = FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
   3      SUBTITLE = BLADED DISC EXAMPLE 5  (CYC MODEL,TIME DEP. LOAD,HARM I/O)
   4      $
   5         SPC    = 30
   6         TSTEP  = 1
   7      OUTPUT
   8         SET 1 = 8,16,18
   9         SET 2 = 11
  10         DLOAD = 1
  11         DISP(SORT2,REAL)    = 1
  12         STRESS(SORT2,REAL) = 2
  13            SUBCASE 1
  14               LABEL = KINDEX 0
  15               DLOAD = 99 $ NULL LOAD
  16            SUBCASE 2
  17               LABEL = KINDEX 1C
  18               DLOAD = 99 $ NULL LOAD
  19            SUBCASE 3
  20               LABEL = KINDEX 1S
  21               DLOAD = 99 $ NULL LOAD
  22            SUBCASE 4
  23               LABEL = KINDEX 2C
  24               DLOAD = 1    $ TIME DEPENDENT LOADS
  25            SUBCASE 5
  26               LABEL = KINDEX 2S
  27               DLOAD = 99 $ NULL LOAD
  28      BEGIN BULK

..MATION MESSAGE 207, BULK DATA NOT SORTED,XSORT WILL RE-ORDER DECK.
```

S O R T E D   B U L K   D A T A   E C H O

. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
CORD2C	1		.0	.0	.0	1.0	.0	.0	&COR12
&COR12	0.0	1.0	0.0						
CQUAD2	4	2	2	3	7	6			
CQUAD2	5	2	6	7	12	11			
CQUAD2	6	2	3	4	8	7			
CQUAD2	7	2	7	8	13	12			
CQUAD2	8	2	4	5	9	8			
CQUAD2	10	2	8	15	14	13			
CQUAD2	11	3	9	16	18	15			
CQUAD2	12	3	16	17	19	18			
CTRIA2	1	1	1	6	10				
CTRIA2	2	1	1	2	6				
CTRIA2	3	1	10	6	11				
CTRIA2	9	1	8	9	15				
CYJOIN	1		1	2	3	4	5		
CYJOIN	2		10	11	12	13	14		
DAREA	1	8	3	-1.0					
DAREA	1	16	3	1.0					
DAREA	1	18	3	1.0					
GRDSET		1				1			
GRID	1		2.0	30.0	.0				
GRID	2		3.1	30.0	.0				
GRID	3		4.3	30.0	.0				
GRID	4		5.2	30.0	.0				
GRID	5		7.1	30.0	.0				
GRID	6		3.1	45.0	.0				
GRID	7		4.3	45.0	.0				
GRID	8		5.2	45.0	.0				
GRID	9		7.1	40.0	.0				
GRID	10		2.0	60.0	.0				
GRID	11		3.1	60.0	.0				
GRID	12		4.3	60.0	.0				
GRID	13		5.2	60.0	.0				
GRID	14		7.1	60.0	.0				
GRID	15		7.1	50.0	.0				
GRID	16		8.5	40.0	-.25				
GRID	17		9.7	40.0	-.50				
GRID	18		8.5	50.0	.25				
GRID	19		9.7	50.0	.50				
MAT1	1	30.0E6		.3	7.4-4				
PARAM	CYCIO	-1							
PARAM	G	.02							
PARAM	GKAD	FREQRESP							
PARAM	KMAX	2							
PARAM	KMIN	2							
PARAM	LGKAD	1							
PARAM	LMAX	1							
PARAM	NSEGS	12							
PARAM	EPS	600.0							
PQUAD2	2	1	.25						

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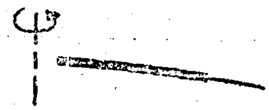
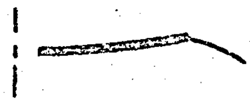
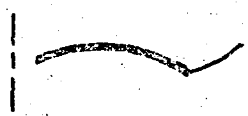
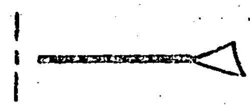
S O R T E D   B U L K   D A T A   E C H O

```
.   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
POLAD2  3       1       .125
PTRIA2  1       1       .25
SPC1    30      6       1       THRU    19
SPC1    30      123456  1       10
TABLED1 9999                                                            &TTT
&TTT    0.0     0.0     1.0     0.0     ENDT
TLOAD1  99      1       0               9999
TLOAD2  1       1                       .0      5.5131-41813.854-90.0
TSTEP   1       10      4.5943-51
ENDDATA
```

TABLE 1: PRINCIPAL FEATURES DEMONSTRATED BY EXAMPLE PROBLEMS

Example No.	Finite Element Model of	Applied loads specified as functions of: Frequency (sinusoidal)		Time (periodic)		Base Acceleration	Rotational Speed
		Physical Components	Circum.Harmonic Components	Physical Components	Circum.Harmonic Components		
1	Complete Structure	Yes				No	No
2	Cyclic Sector	Yes				No	No
3	Cyclic Sector		Yes			Yes	Yes
4	Cyclic Sector			Yes		No	Yes
5	Cyclic Sector				Yes	No	Yes

TABLE 2: BLADED-DISC NATURAL FREQUENCIES

Frequency (Mode No.), Hz.			Mode Description
k* = 0	k = 1	k = 2	
214 (1)	208 (1)	242 (1)	
591 (2)	594 (2)	622 (2)	
1577 (3)	1633 (3)	1814 (3)	
2468 (5)**	2460 (4)	2433 (4)	

* k is the circumferential harmonic index

** Mode No. 4 for k = 0 at 1994 Hz represents an in-plane shear mode not excited by the applied forces.

TABLE 3: EFFECT OF CORIOLIS AND CENTRIPETAL ACCELERATIONS ON THE DISPLACEMENT RESPONSE OF GRID POINT 18 AT 600 RPS.

Frequency Hz	Example 2 Segment 1 (subcase 1) Mag. (in)/Phase (deg)	Example 3 k = 2c (subcase 4) Mag. (in)/Phase (deg)
1700	7.2655 E-5/349.4	7.6132 E-5/354.3
1750	1.3071 E-4/343.1	1.3844 E-4/347.3
1778	2.1580 E-4/332.7	2.3252 E-4/335.8
1796	3.4139 E-4/314.6	3.7252 E-4/315.2
1814	4.8374 E-4/269.9	4.9177 E-4/266.8
1832	3.4146 E-4/224.9	3.2655 E-4/225.5
1850	2.1451 E-4/206.6	2.0742 E-4/209.3
1880	1.2433 E-4/195.6	1.2214 E-4/199.2
1920	7.6125 E-5/190.4	7.5397 E-5/194.3

TABLE 4: COMPARISON OF RESPONSE AT 1814 Hz

Grid Pt.Disp. or Elem. Stresses	Example 3 k = 2c (subcase 4) Mag.(in)/Phase(deg)	Example 4 Segment 1 (subcase 1) Mag.(in)/Phase(deg)	Example 5 k = 2c (subcase 4) Mag.(in)/Phase(deg)
8 (T3RM), u_z	5.4297 E-4/82.6	5.4299 E-4/82.6	5.4299 E-4/82.6
18 (T3RM), u_z	4.9177 E-4/266.8	4.9180 E-4/266.8	4.9180 E-4/266.8
11 (3), $\sigma_{xx,1}$*	1.4841 E 3/84.7	1.4842 E 3/84.7	1.4842 E3/84.7
11 (5), $\sigma_{yy,1}$	2.0891 E 2/83.4	2.0892 E 2/83.4	2.0892 E2/83.4
11 (7), $\tau_{xy,1}$	1.0774 E 2/64.7	1.0775 E 2/64.7	1.0775 E2/64.7
11 (10), $\sigma_{xx,2}$*	1.4677 E 3/263.3	1.4678 E3/263.3	1.4678 E3/263.3
11 (12), $\sigma_{yy,2}$	2.2489 E 2/260.3	2.2491 E 2/260.4	2.2491 E2/260.4
11 (14), $\tau_{xy,2}$	1.8510 E 2/253.0	1.8511 E 2/253.0	1.8512 E2/253.0

* Fibre distances 1 and 2.

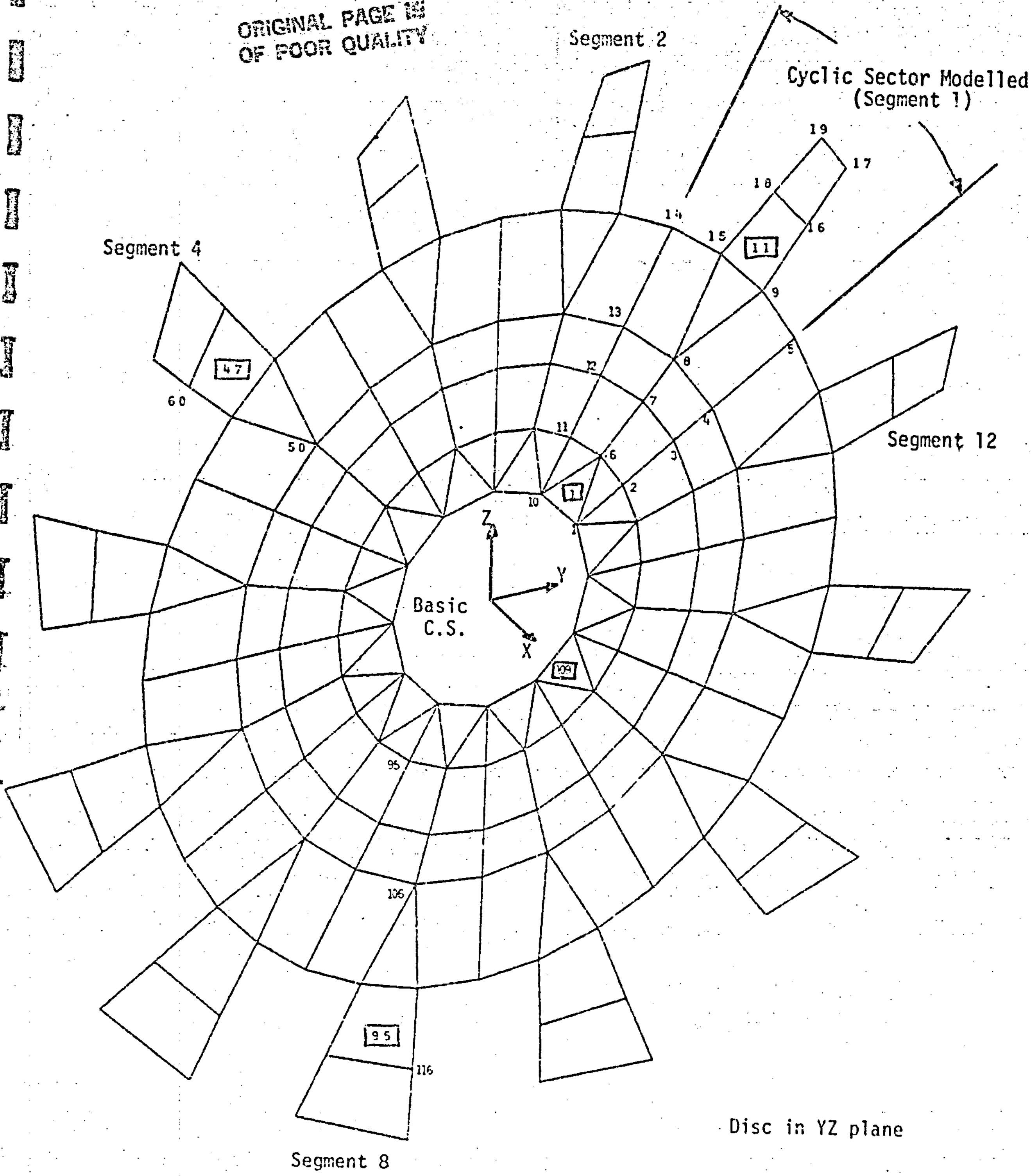


Figure 1: NASTRAN Model of the 12-Bladed Disc

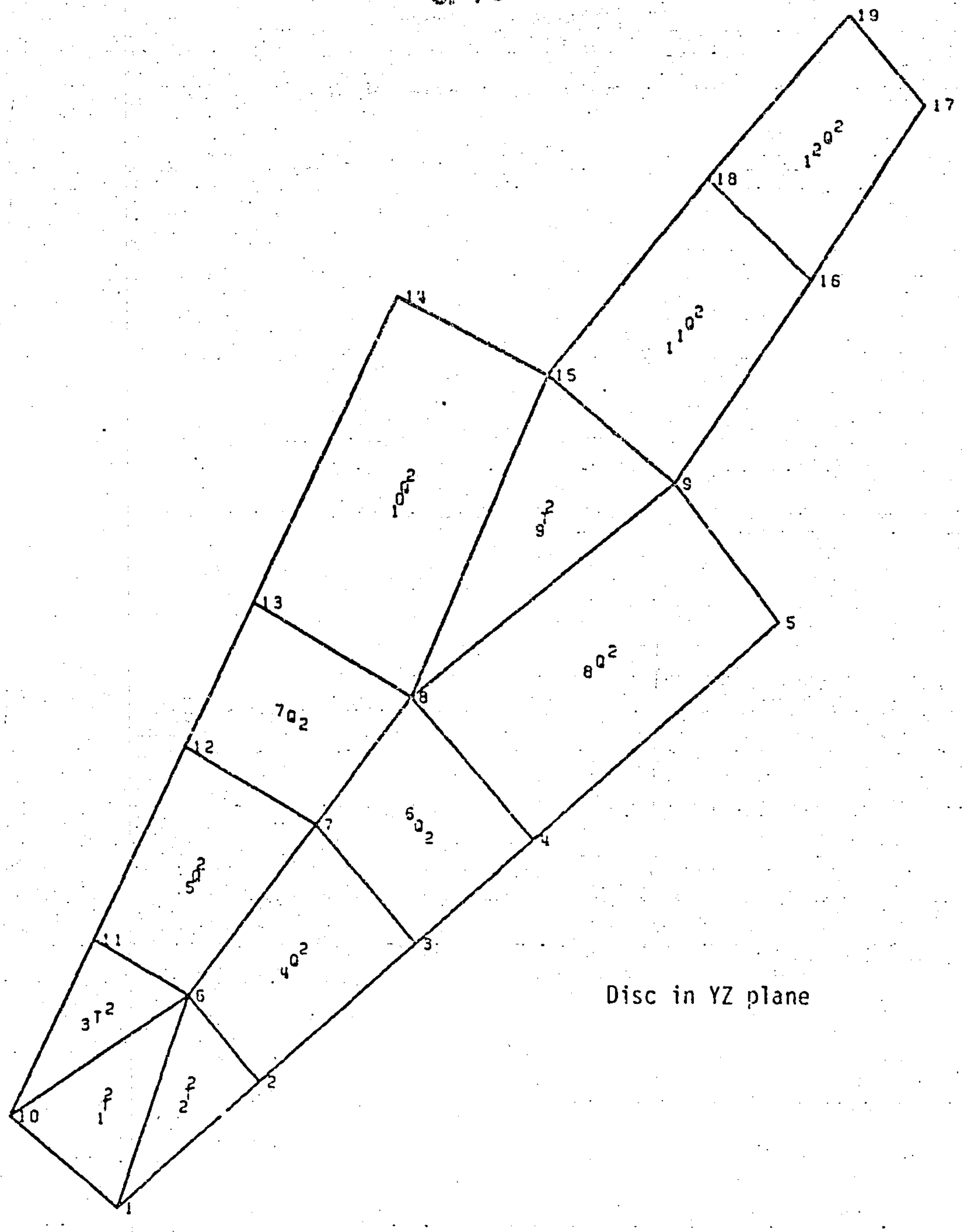


Figure 2: NASTRAN Cyclic Model of the 12-Bladed Disc

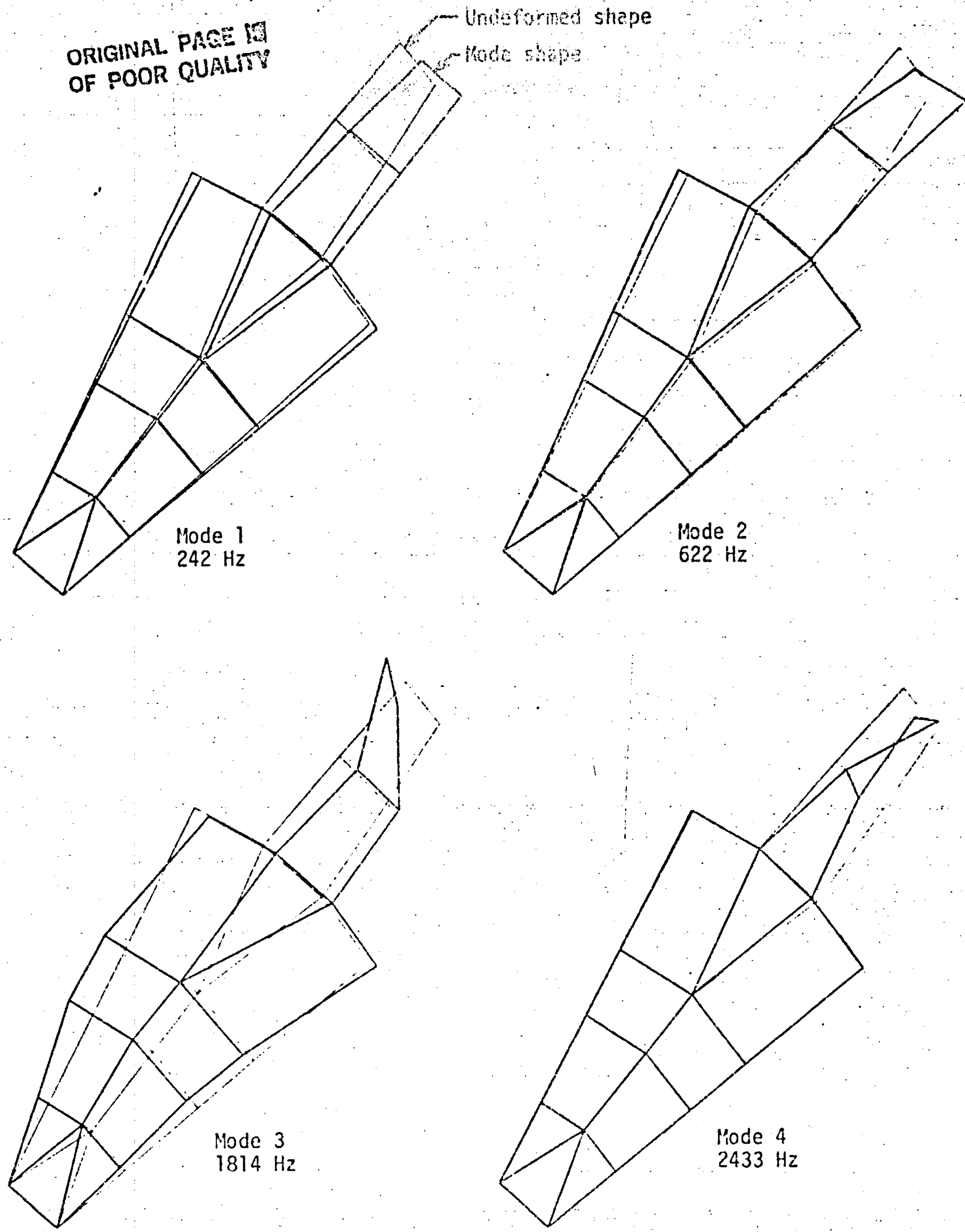
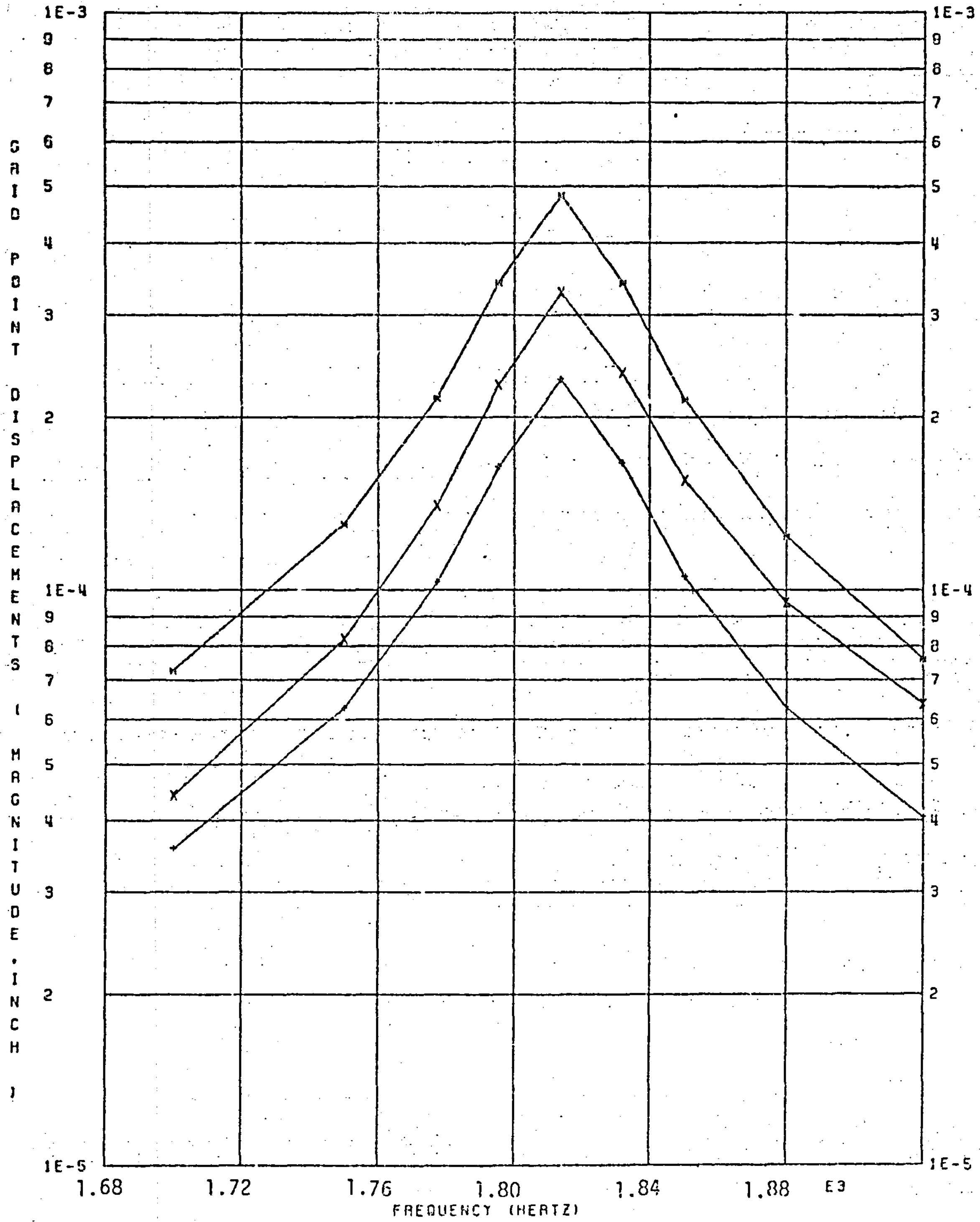
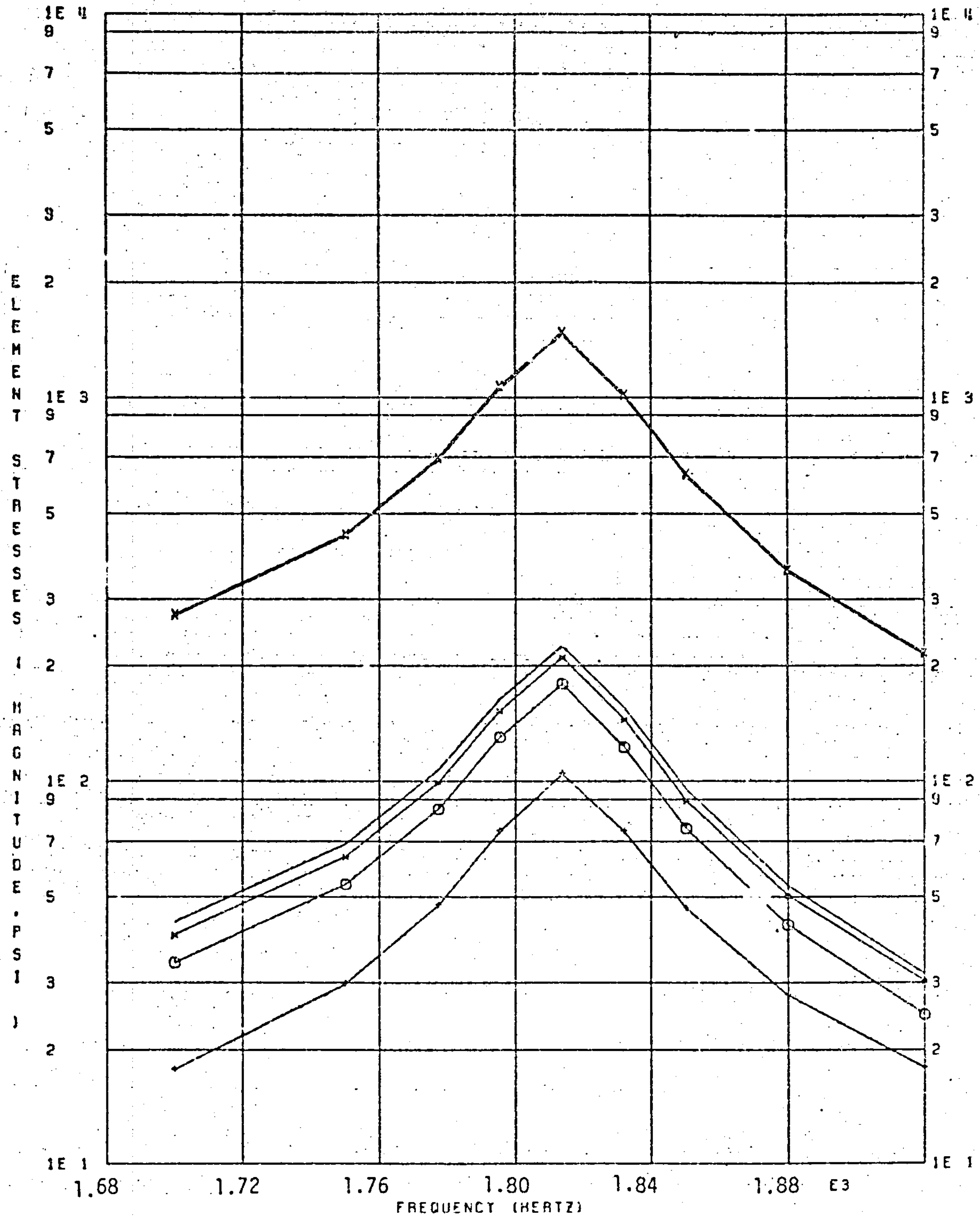


Figure 3: k = 2 Modes of Bladed Disc



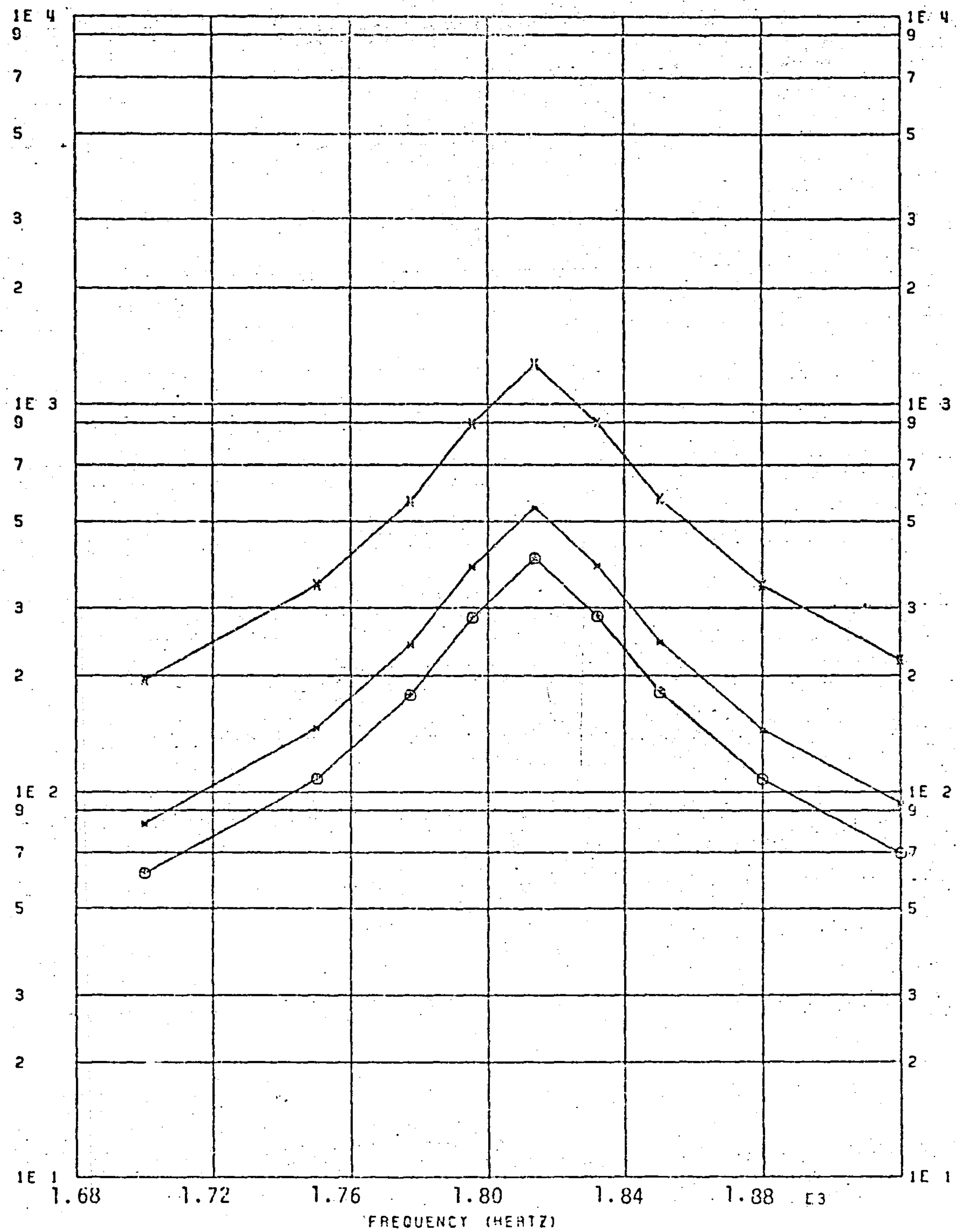
14(T3AM),18(T3AM),95(T3AM)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 1 (FULL MODEL,FREQ LOADS)
KINDEX 2C TYPE LOADS

Figure 4



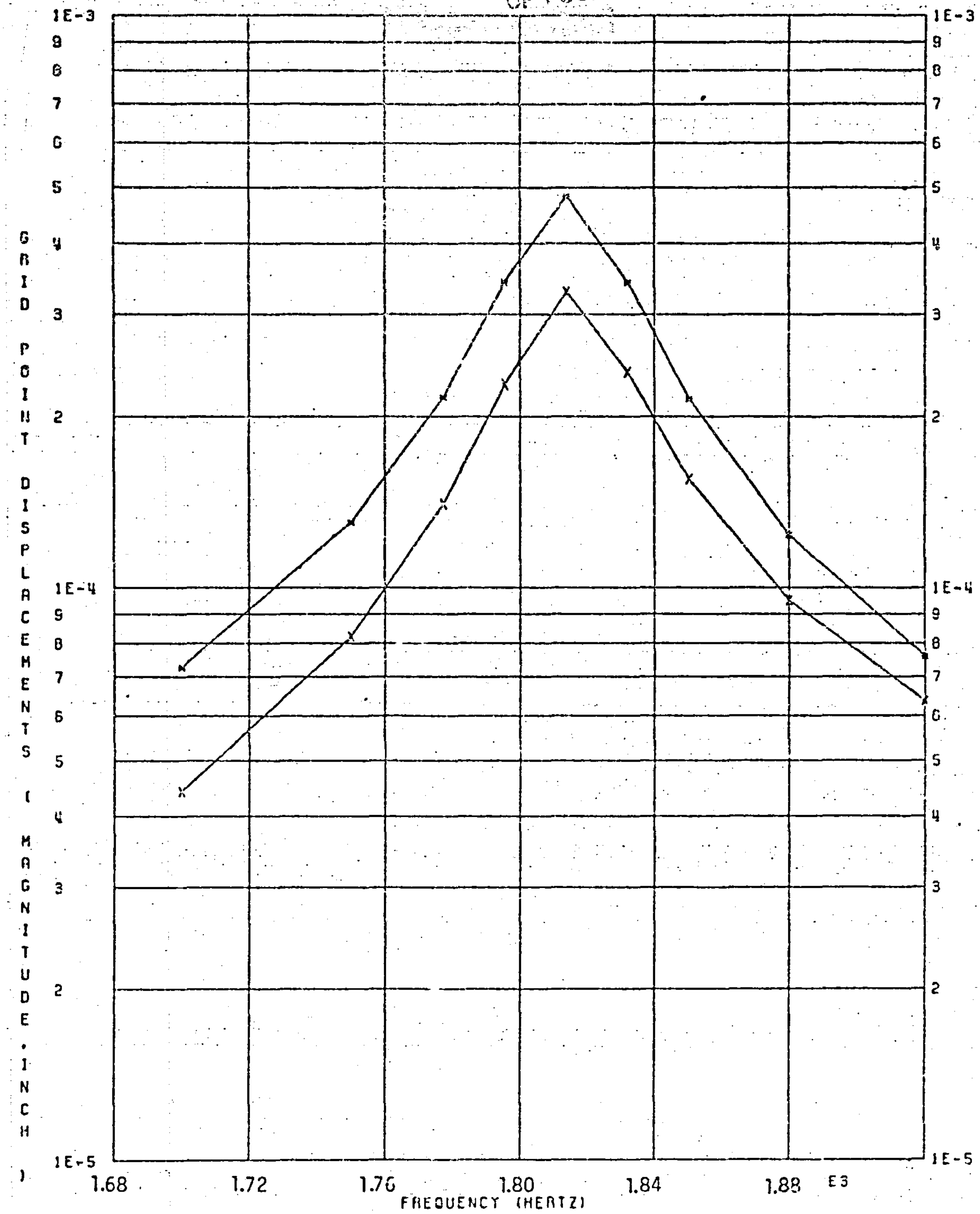
11(3),11(5),11(7),11(10),11(12),11(14)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 1 (FULL MODEL,FREQ LOADS)
KINDEX 2C TYPE LOADS

Figure 5



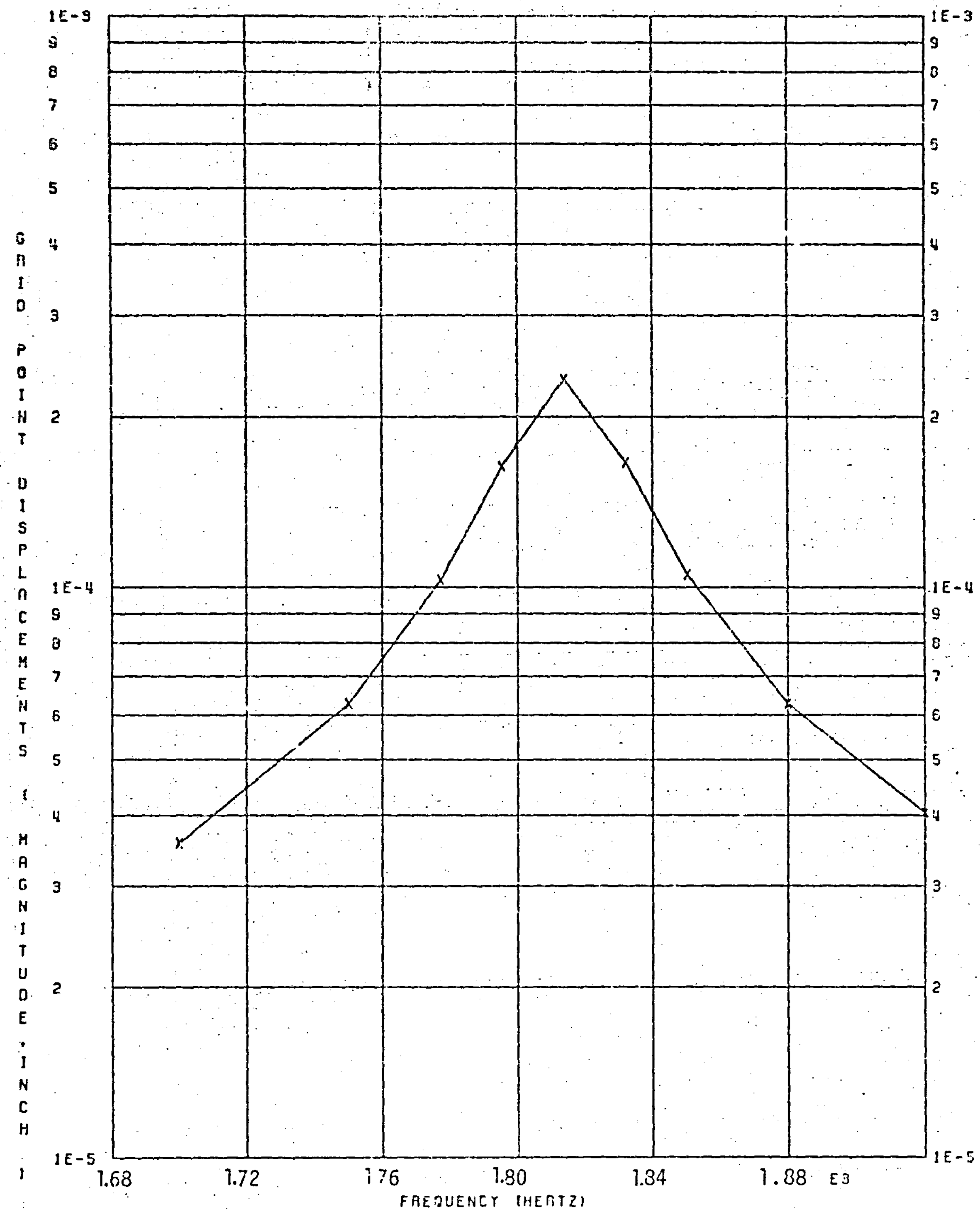
109(3),109(5),109(7),109(10),109(12),109(14)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED D'SC EXAMPLE 1 (FULL MODEL,FREQ LOADS)
KINDEX 2C TYPE LOADS

Figure 6



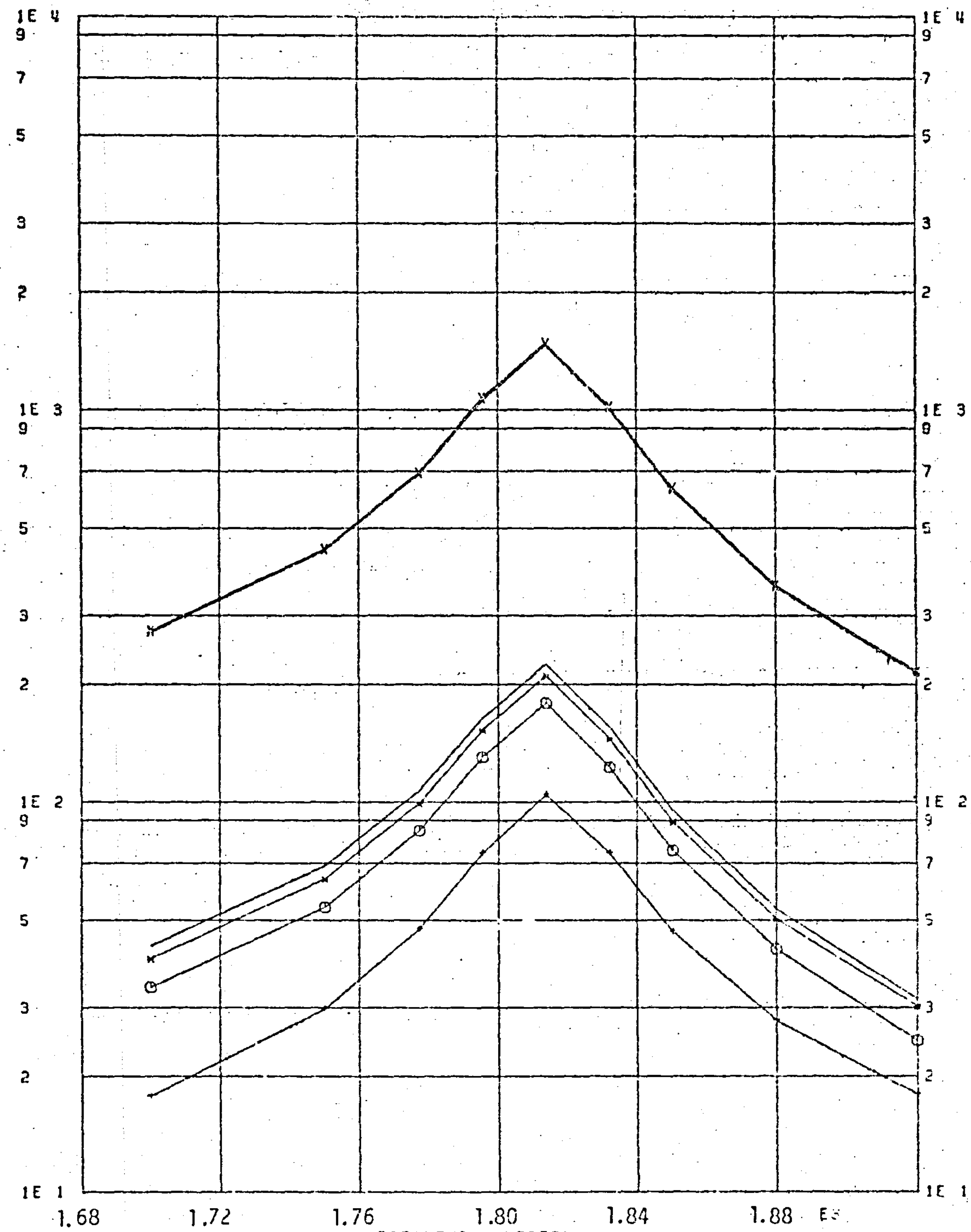
14(T3RM),18(T3RM)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 2 (CYC MODEL,FREQ LOADS,PHYSICAL I/O)
SEGMENT 1 SUBCASE 1

Figure 7



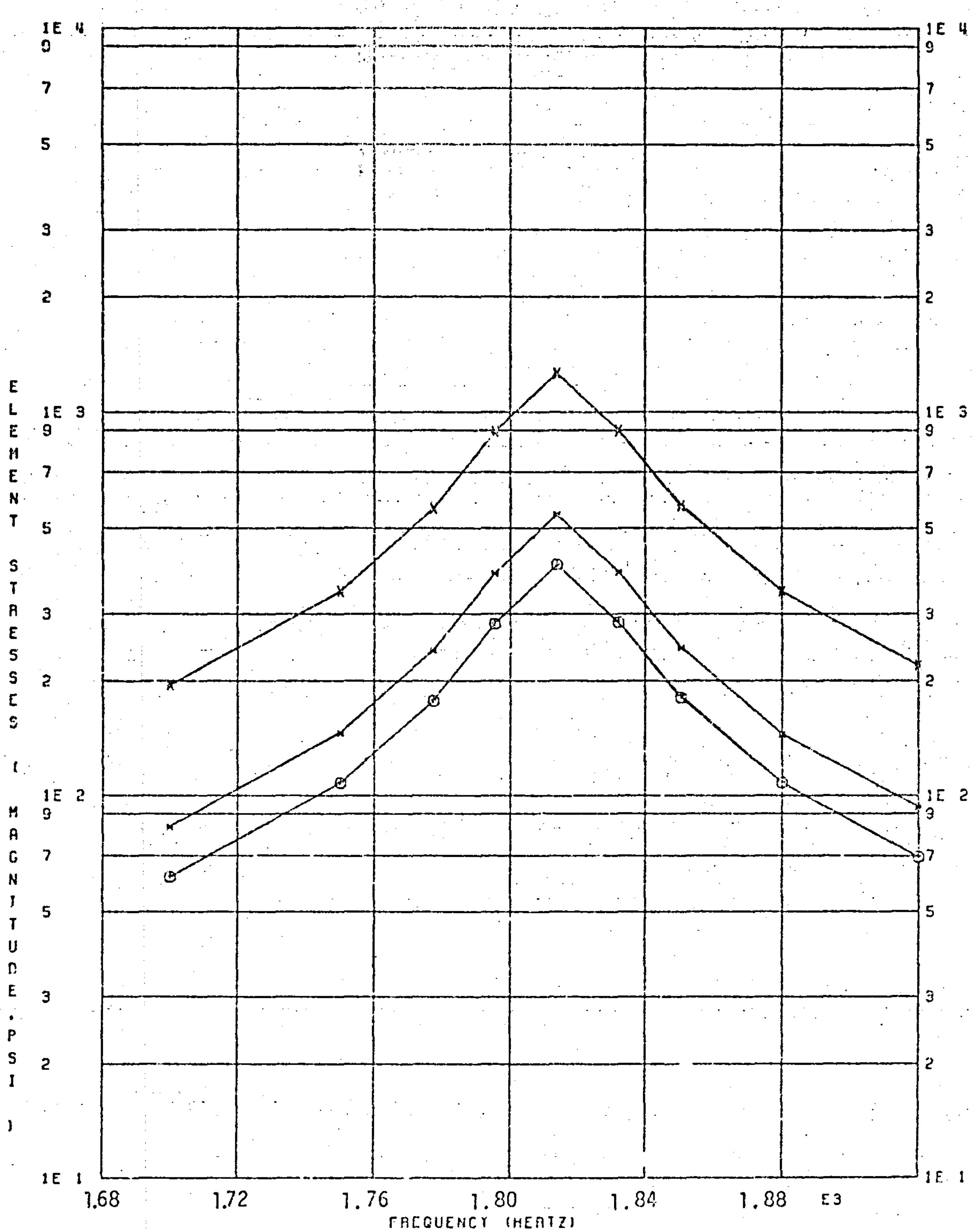
2(T3RM)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 2 (CYC MODEL,FREQ LOADS,PHYSICAL I/O)
SEGMENT 8 SUBCASE 8

Figure 8



11(3),11(5),11(7),11(10),11(12),11(14)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 2 (CYC MODEL,FREQ LOADS,PHYSICAL I/O)
SEGMENT 1 SUBCASE 1

Figure 9



1(3),1(5),1(7),1(10),1(12),1(14)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 2 (CYC MODEL,FREQ LOADS,PHYSICAL I/O)
SEGMENT 10 SUBCASE 10

Figure 10

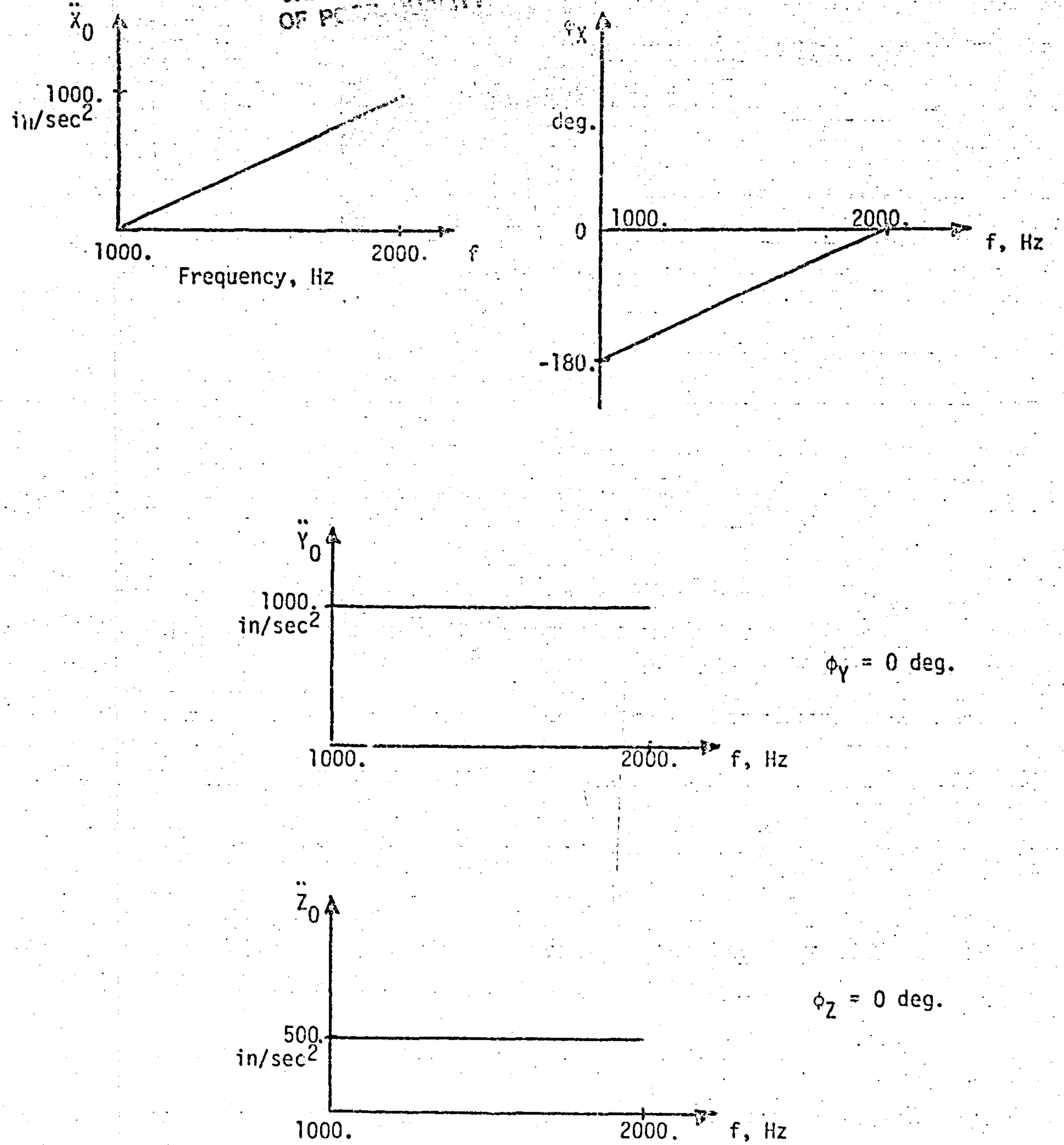
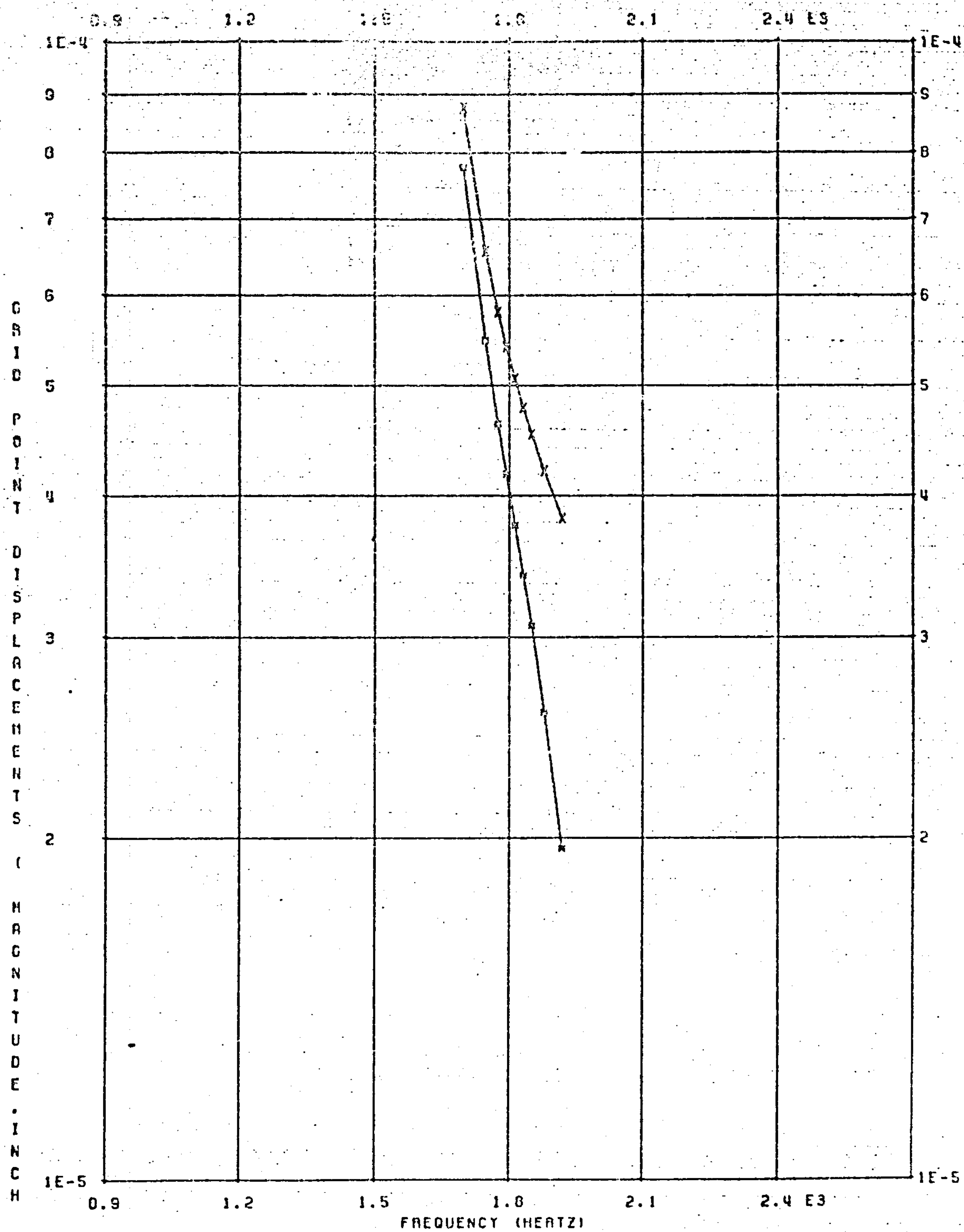
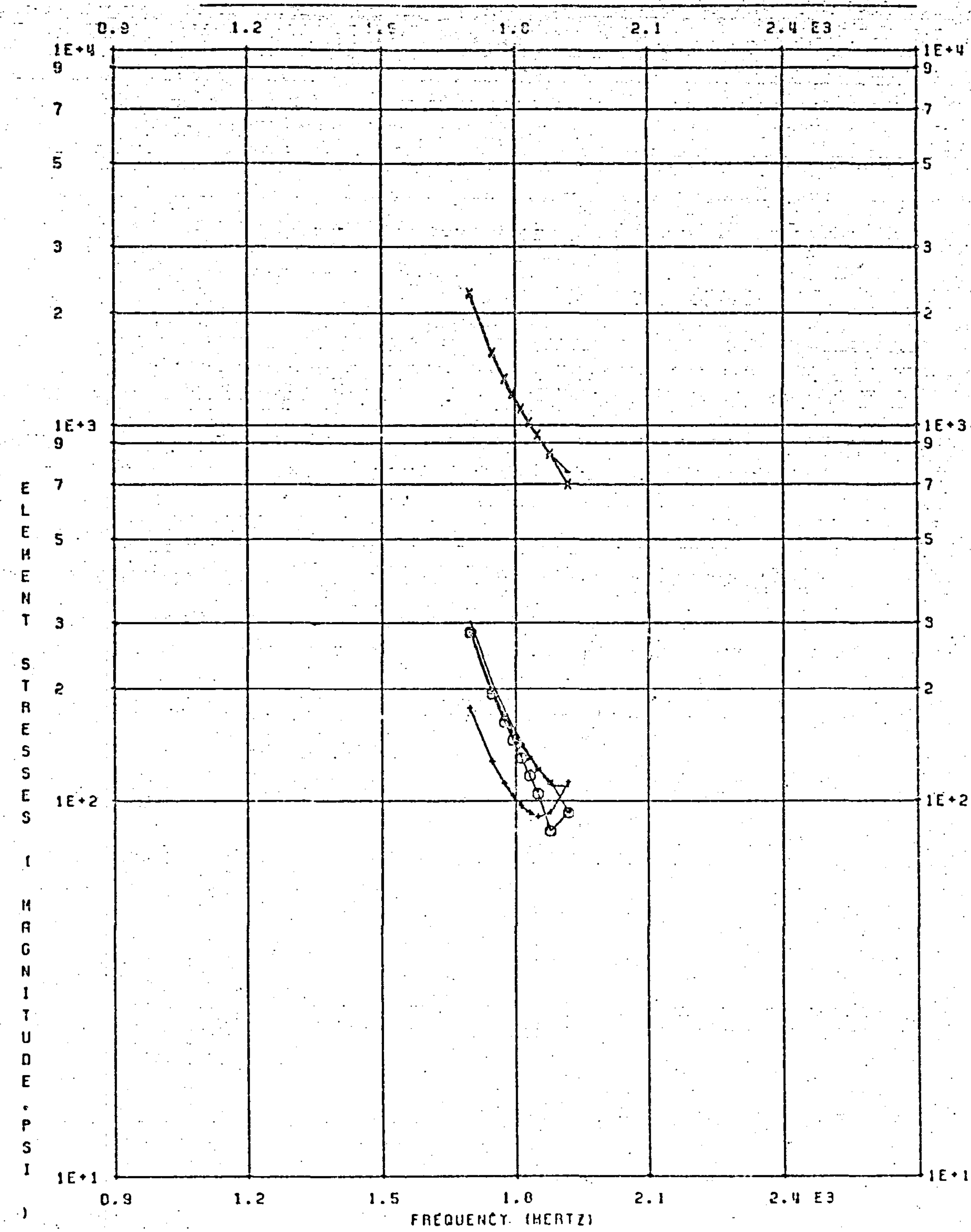


Figure 11: Base Acceleration Data in an Inertial Coordinate System



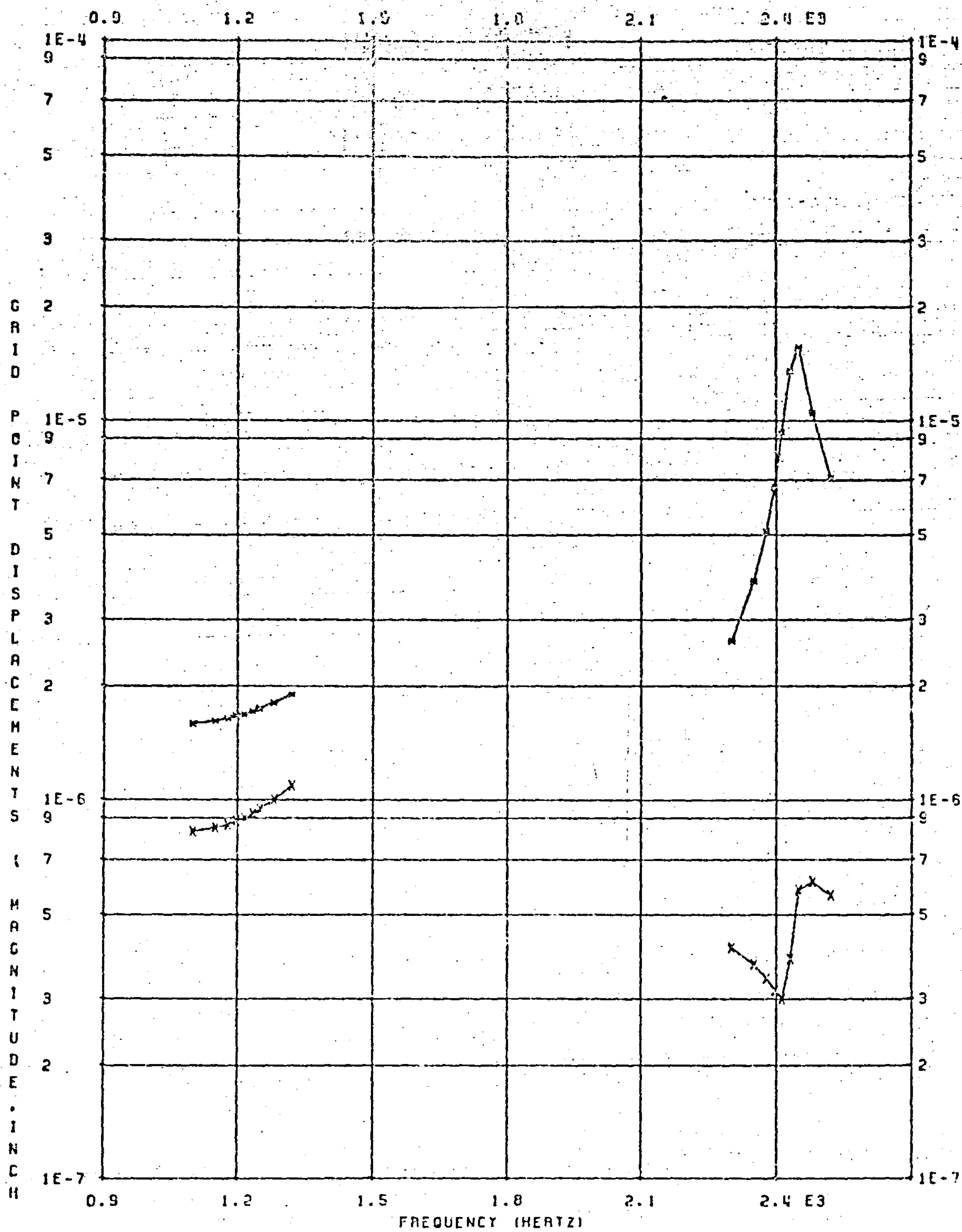
8(T3RM),18(T3RM)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 3 (CYC MODEL,FREQ+BASE ACCN LOAD,HARM I/O
KINDEX 0 SUBCASE 1

Figure 12



11(9),11(5),11(7),11(10),11(12),11(14)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 3 (CYC MODEL,FREQ+BASE ACCN LOAD,HARM I/O
KINDEX 0 SUBCASE 1

Figure 13



8(T3AM),18(T3AM)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 3 (CYC MODEL,FREQ+BASE ACCN LOAD,HARM 1/0
KINDEX 1C SUBCASE 2

Figure 14

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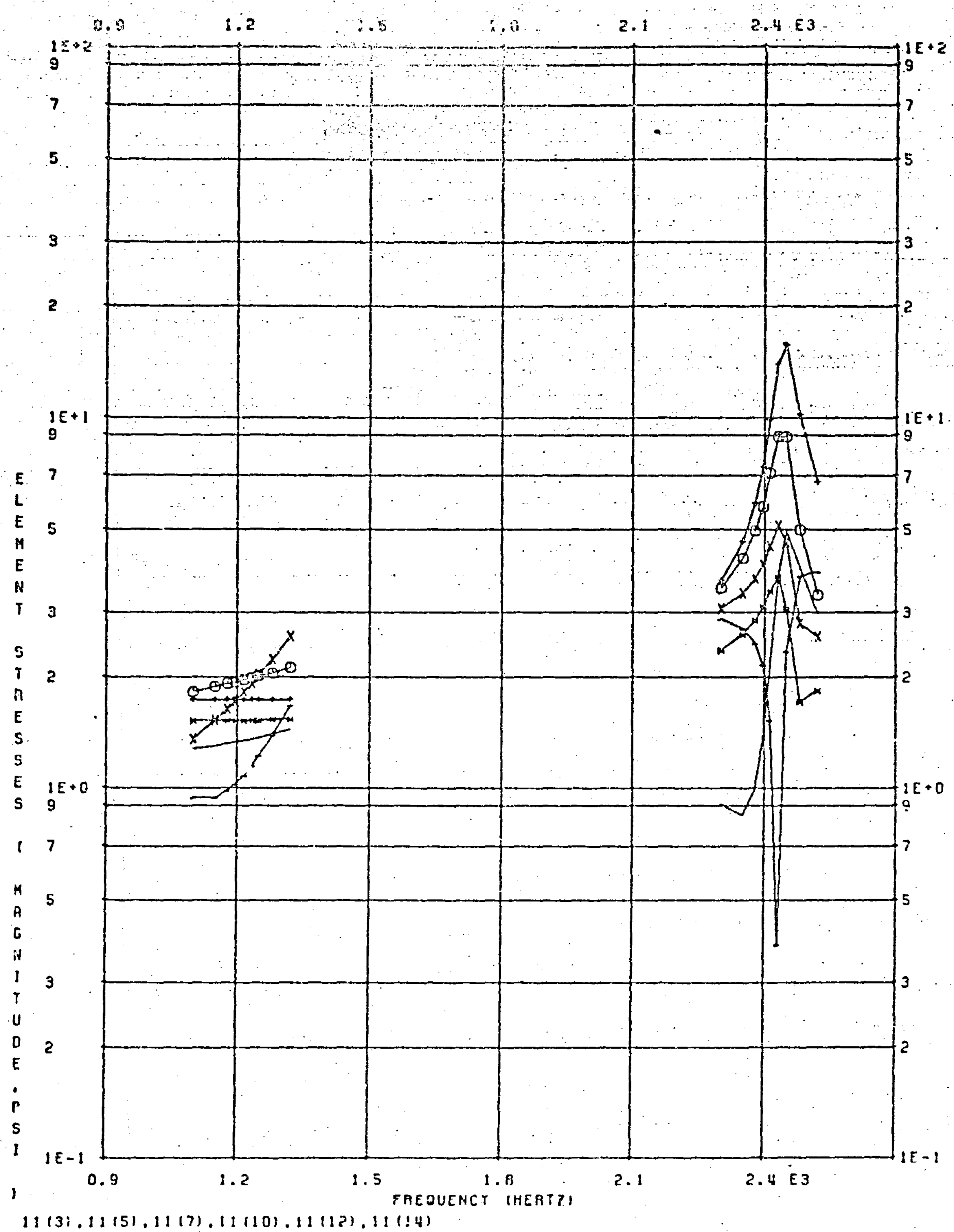
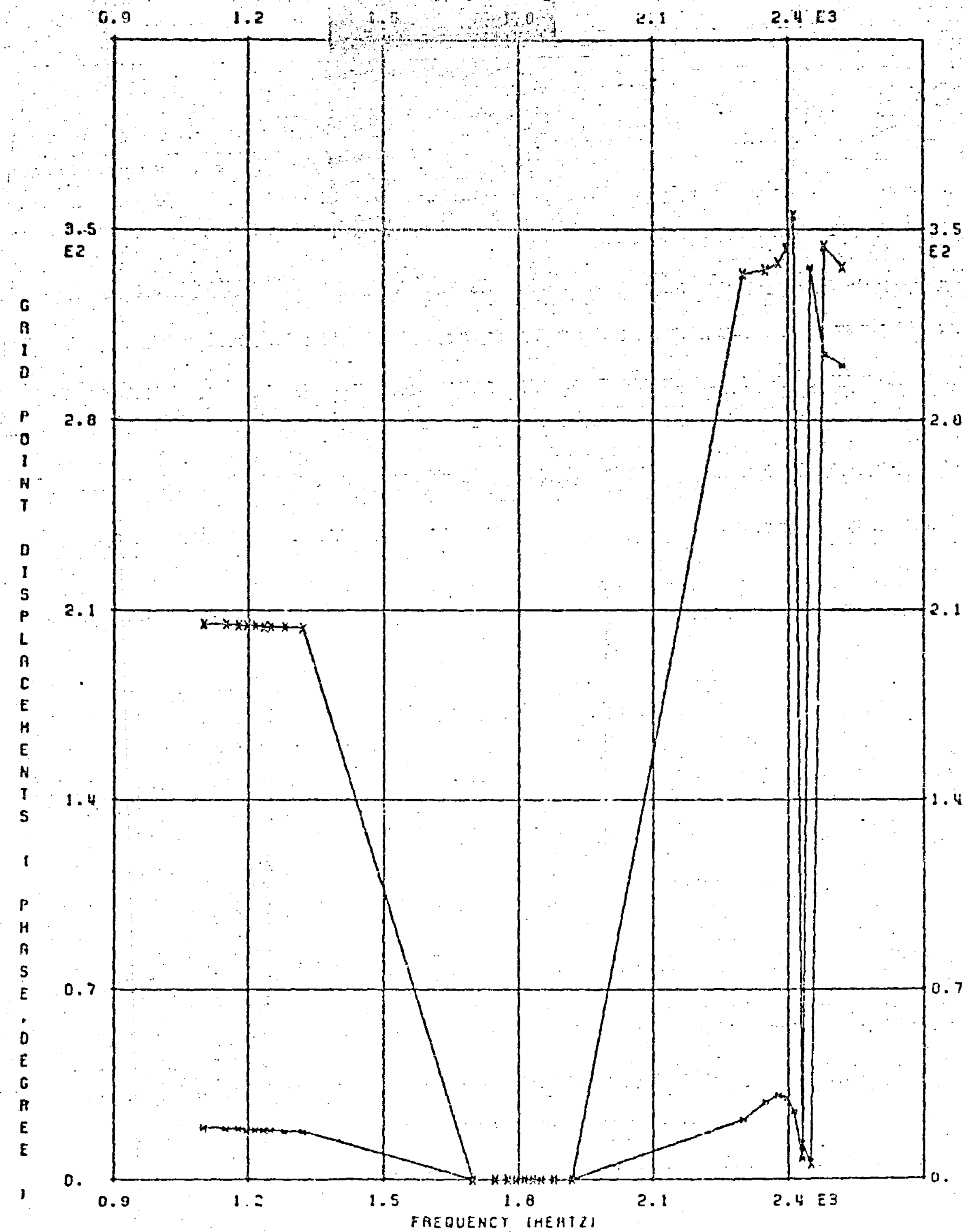


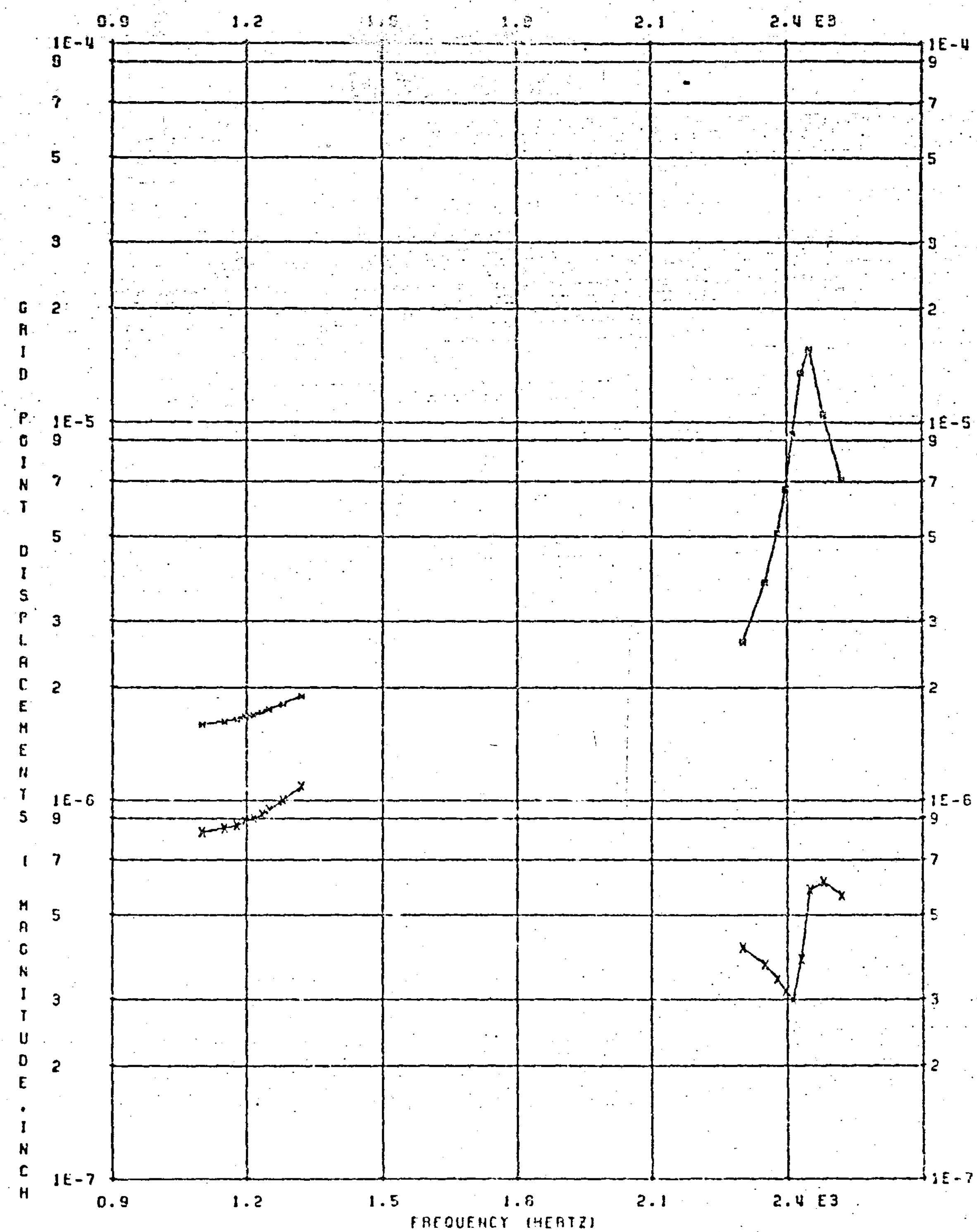
11(3),11(5),11(7),11(10),11(12),11(14)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 3 (CYC MODEL,FREQ+BASE ACCN LOAD,HARM I/O
KINDEX 1C SUBCASE 2

Figure 15



8(T3IP),10(T3IP)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 3 (CYC MODEL,FREQ+BASE ACCN LOAD,HARM I/O
KINDEX 1C SUBCASE 2

Figure 16



8(T3RM),18(T3RM)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 3 (CYC MODEL,FREQ+BASE ACCN LOAD,HARM 1/0
KINDEX 1S SUBCASE 3

Figure 17

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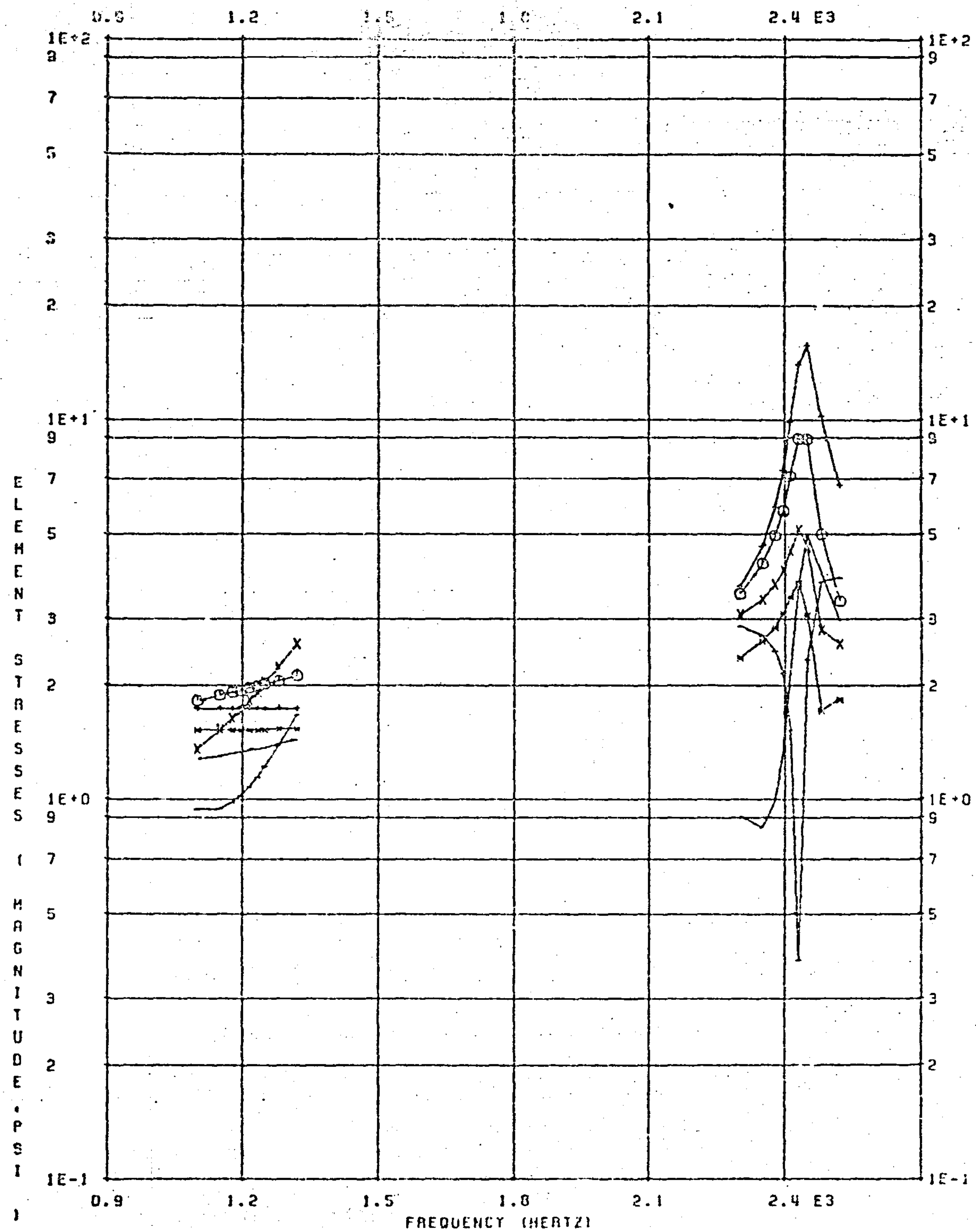
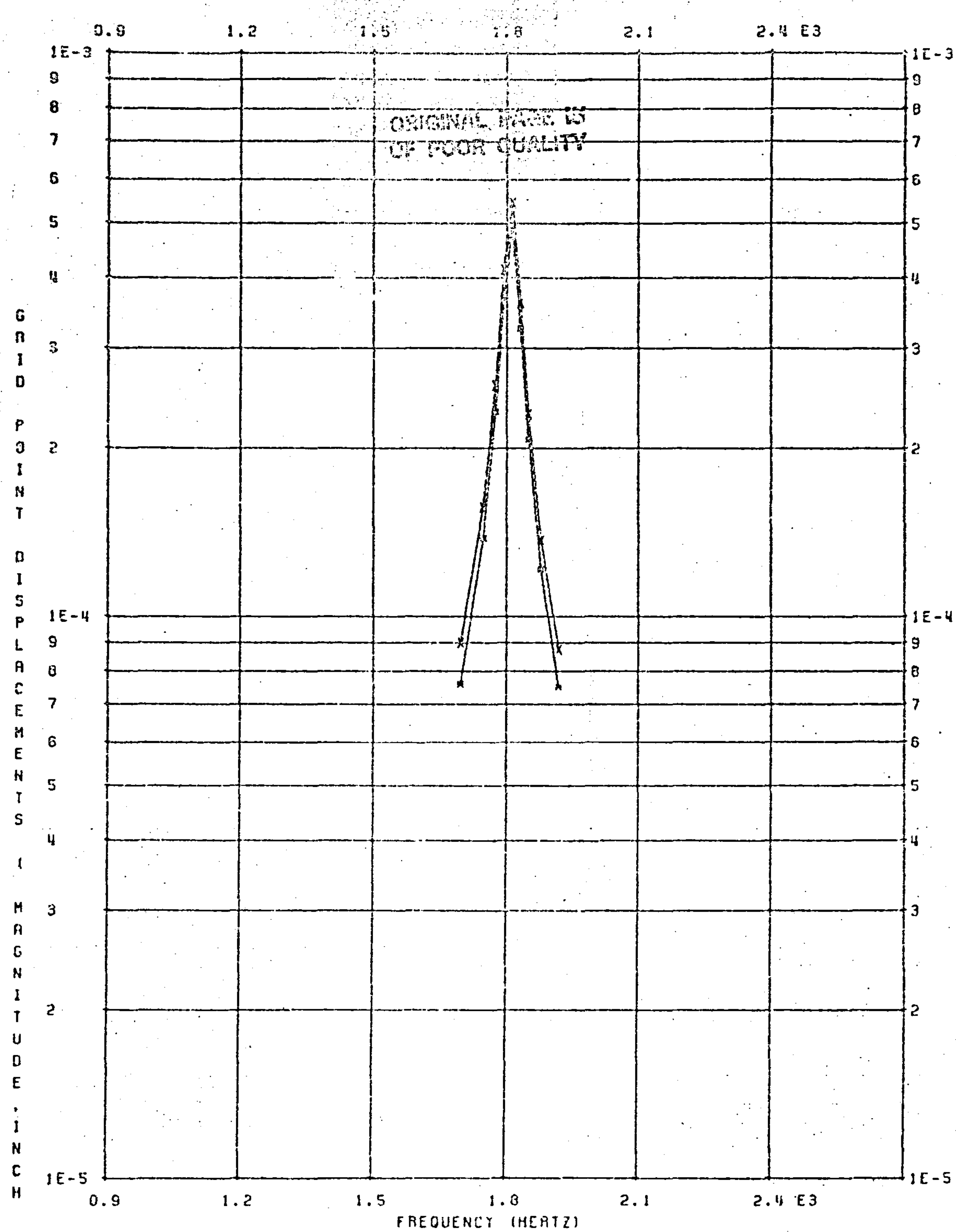


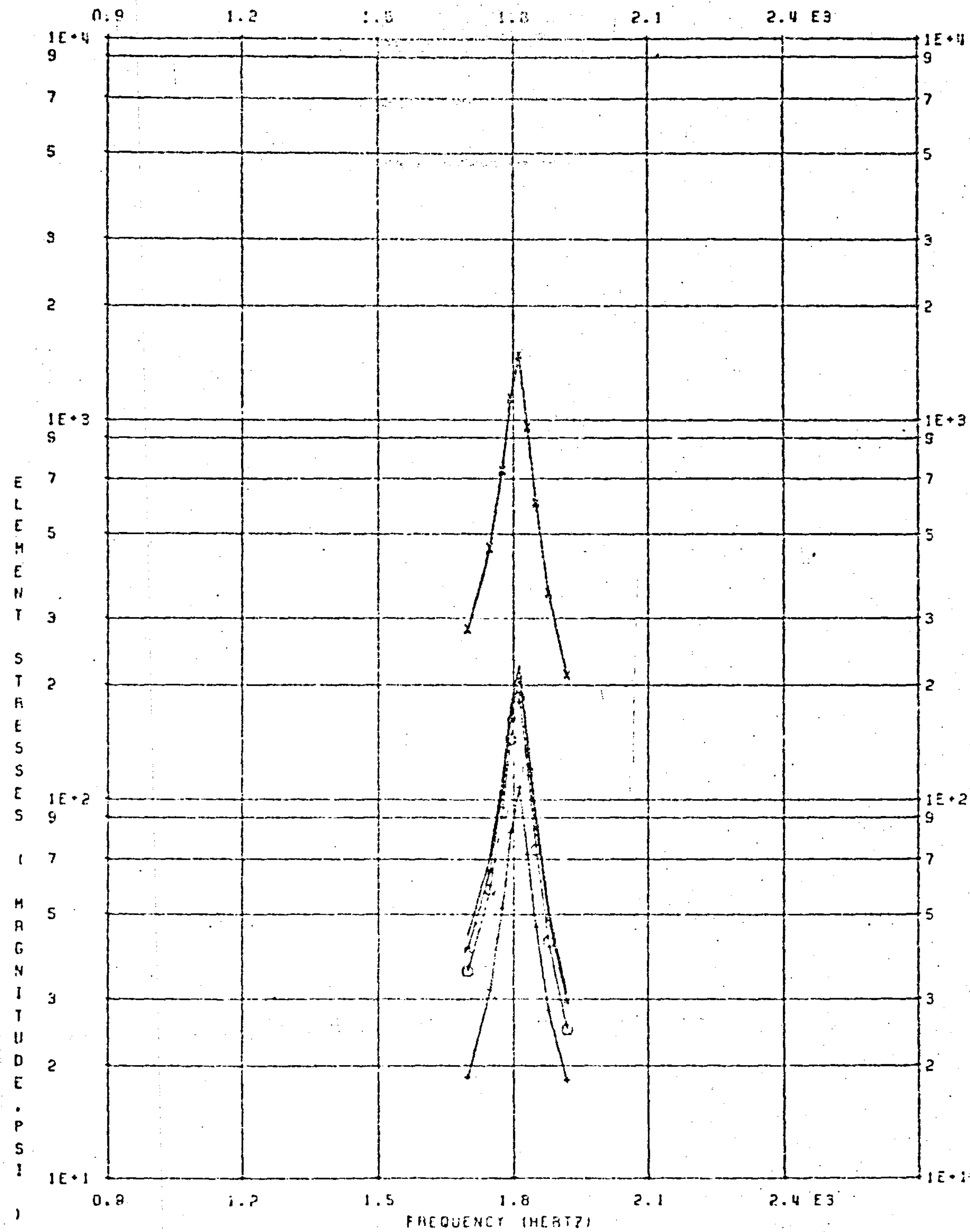
11(3),11(5),11(7),11(10),11(12),11(14)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 3 (CYC MODEL,FREQ+BASE ACCN LOAD,HARM 1/0
KINDEX 15 SUBCASE 3

Figure 18



8(T3RM),18(T3RM)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 3 (CYC MODEL,FREQ+BASE ACCN LOAD,HARM 1'0
KINDEX 2C SUBCASE 4

Figure 19



11(3),11(5),11(7),11(10),11(12),11(14)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 3 (CYC MODEL,FREQ+BASE ACCN LOAD,HARM 1/C
KINDEX 2C SUBCASE 4

Figure 20

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