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FORCED VIBRATION ANALYSIS
OF ROTATING CYCLIC STRUCTURES
IN NASTRAN

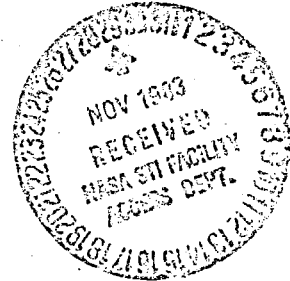
(NASA-CR-165429) FORCED VIBRATION ANALYSIS
OF ROTATING CYCLIC STRUCTURES IN NASTRAN
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by

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A. Michael Gallo
S. C. Skalski

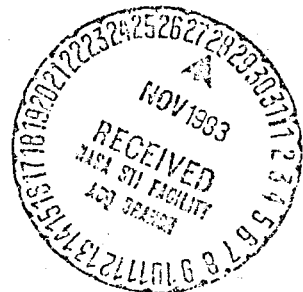


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1. THEORETICAL BASIS

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

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

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.,

$$B^n = B_{\text{viscous}}^n + 2\Omega B_{\text{Coriolis}}^n + B_{\text{structural}}^n \quad (2)$$

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.,

$$K^n = K_{\text{elastic}}^n + K_{\text{differential}}^n - \Omega^2 M_{\text{centripetal}}^n \quad (3)$$

The derivation of the coefficient matrices B_{Coriolis}^n , $M_{\text{centripetal}}^n$ 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),

$$u_{\text{side 1}}^{n+1} = u_{\text{side 2}}^n, \quad n = 1, 2, \dots, N, \quad (4)$$

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

$$P^m = P^0 + \sum_{\ell=1}^{\ell_L} \left[P^{\ell c} \cos((m-1)\ell b) + P^{\ell s} \sin((m-1)\ell b) \right] + (-1)^{m-1} P^{M/2}, \quad (5)$$

$$m = 1, 2, \dots, M,$$

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 P^{ℓ}

(" ℓ " = 0; ℓc , ℓs , $\ell=1, 2, \dots, \ell_L$; $M/2$) in equation (5) are independent of time, and are defined by the relations

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

$$\left. \begin{aligned}
 -\ell c \\
 p^n &= \frac{2}{M} \sum_{m=1}^M p^m \cos(\overline{m-1} \ell c b), \\
 -\ell s \\
 p^n &= \frac{2}{M} \sum_{m=1}^M p^m \sin(\overline{m-1} \ell s b), \text{ and} \\
 -M/2 \\
 p^n &= \frac{1}{M} \sum_{m=1}^M (-1)^{m-1} p^m \quad (M \text{ even only}) \quad (\ell=M/2).
 \end{aligned} \right\} (\ell=1, 2, \dots, \ell_L) \quad (6 \text{ Contd.})$$

Each of the coefficient vectors \overline{p}^{ℓ} on the left hand sides of equations (6) can further be expanded in a circumferential (truncated) Fourier series

$$\overline{p}^{\ell} = \overline{p}^0 + \sum_{k=1}^{k_L} \left[\overline{p}^{kc} \cos(\overline{n-1} k a) + \overline{p}^{ks} \sin(\overline{n-1} k a) \right] + (-1)^{n-1} \overline{p}^{N/2}, \quad (7)$$

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

The last term in equation (7) exists only when N is even. The Fourier

coefficients \overline{p}^k ($k = 0; kc, ks, k = 1, 2, \dots, k_L; N/2$) in equation (7) do not vary from sector to sector, and are defined by

$$\left. \begin{aligned}
 \overline{p}^0 &= \frac{1}{N} \sum_{n=1}^N p^n \quad (k=0) \\
 \overline{p}^{kc} &= \frac{2}{N} \sum_{n=1}^N p^n \cos(\overline{n-1} k a) \\
 \overline{p}^{ks} &= \frac{2}{N} \sum_{n=1}^N p^n \sin(\overline{n-1} k a), \text{ and} \\
 \overline{p}^{N/2} &= \frac{1}{N} \sum_{n=1}^N (-1)^{n-1} p^n \quad (N \text{ even only}) \quad (k=N/2)
 \end{aligned} \right\} (9)$$

The terms $\bar{p}^{-\ell k}$ (" ℓ " = 0; $\ell c, \ell s, \ell = 1, 2, \dots, \ell_L; M/2$ and " k " = 0; $k c, k s, k = 1, 2, \dots, k_L; N/2$) are the transformed frequency-dependent circumferential harmonic components of the directly applied loads p^m ($m = 1, 2, \dots, M$ and $n = 1, 2, \dots, N$).

Directly applied loads (Circumferential harmonic-dependent and periodic in time).

Such loads can be represented as

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

where $m = 1, 2, \dots, M$ represent the time instances at which harmonic components " k " = 0; $k c, k s, k = 1, 2, \dots, k_L; N/2$ 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 ".

Directly applied loads (frequency-and segment-dependent)

This type of loads can be represented as

$$\bar{p}^n = \bar{p}^0 + \sum_{k=1}^{k_L} \left[\bar{p}^{-\ell k c} \cos(n-1 k a) + \bar{p}^{-\ell k s} \sin(n-1 k a) \right] + (-1)^{n-1} \bar{p}^{-N/2}, \quad (11)$$

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; $k c, k s, k = 1, 2, \dots, k_L; N/2$) are obtained using equations (9) with " ℓ " as defined above.

Directly applied loads (frequency-and circumferential harmonic-dependent)

These loads are the transformed frequency-dependent circumferential harmonic components $\bar{p}^{-\ell k}$ (" k " = 0; $k c, k s, k = 1, 2, \dots, k_L; N/2$) with " ℓ " (=1, 2, ..., F) representing the various frequencies at which the directly applied loads are specified.

Base acceleration (frequency- and circumferential harmonic-dependent)

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 $\bar{P}^{\ell k}$ where "k" = 0, and "ℓ" represents the specified excitation frequencies.
2. Lateral components contribute to $\bar{P}^{\ell k}$ 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 $-M_2^{\eta} \ddot{R}$ 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:

$$\begin{array}{rcc}
 \text{side 2} & \text{side 1} & \\
 \bar{u}_2^0 & = & \bar{u}_1^0 \quad (k = 0) \\
 \bar{u}_2^{kc} & = & \bar{u}_1^{kc} \cos(ka) + \bar{u}_1^{ks} \sin(ka) \\
 \bar{u}_2^{ks} & = & -\bar{u}_1^{kc} \sin(ka) + \bar{u}_1^{ks} \cos(ka) \\
 \text{and } \bar{u}_2^{N/2} & = & -\bar{u}_1^{N/2} \quad (k = N/2)
 \end{array} \quad \left. \vphantom{\begin{array}{r} \bar{u}_2^0 \\ \bar{u}_2^{kc} \\ \bar{u}_2^{ks} \\ \bar{u}_2^{N/2} \end{array}} \right\} (k = 1, 2, \dots, k_L) \quad (12)$$

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

$$\begin{array}{r}
 \bar{u}^{kc} = G_{ck}(k) \bar{u}^k, \text{ and} \\
 \bar{u}^{ks} = G_{sk}(k) \bar{u}^k
 \end{array} \quad (13)$$

\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 = 0 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)

$$\bar{M}^k \bar{u}^k + \bar{B}^k \dot{\bar{u}}^k + \bar{K}^k \bar{u}^k = \bar{p}^k \quad (14)$$

where $\bar{M}^k = G_{ck}^T M^n G_{ck} + G_{sk}^T M^n G_{sk}$,

$$\bar{B}^k = G_{ck}^T B^n G_{ck} + G_{sk}^T B^n G_{sk}$$

$$\bar{K}^k = G_{ck}^T K^n G_{ck} + G_{sk}^T K^n G_{sk}, \text{ and}$$

$$\bar{p}^k = G_{ck}^T \bar{p}^{kc} + G_{sk}^T \bar{p}^{ks}$$

(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

$$\bar{p}^k = \bar{p}^k e^{i\omega' t} \quad \text{and accordingly,}$$

$$\bar{u}^k = \bar{u}^k e^{i\omega' t}$$

(16)

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

$$[-\omega'^2 \bar{M}^k + i\omega' \bar{B}^k + \bar{K}^k] \bar{u}^k = \bar{p}^k \quad (17)$$

The excitation frequency ω' is given by

$$\omega' = \omega \text{ for all directly applied and axial base acceleration loads, and}$$

$$= \omega \pm \Omega \text{ for lateral base acceleration loads.}$$

(18)

Equation (17) is solved for \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^{ℓ} in various segments with " ℓ " = 0; &c, &s, $\ell = 1, 2, \dots, \ell_{\max}$. 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^{ℓ} 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.

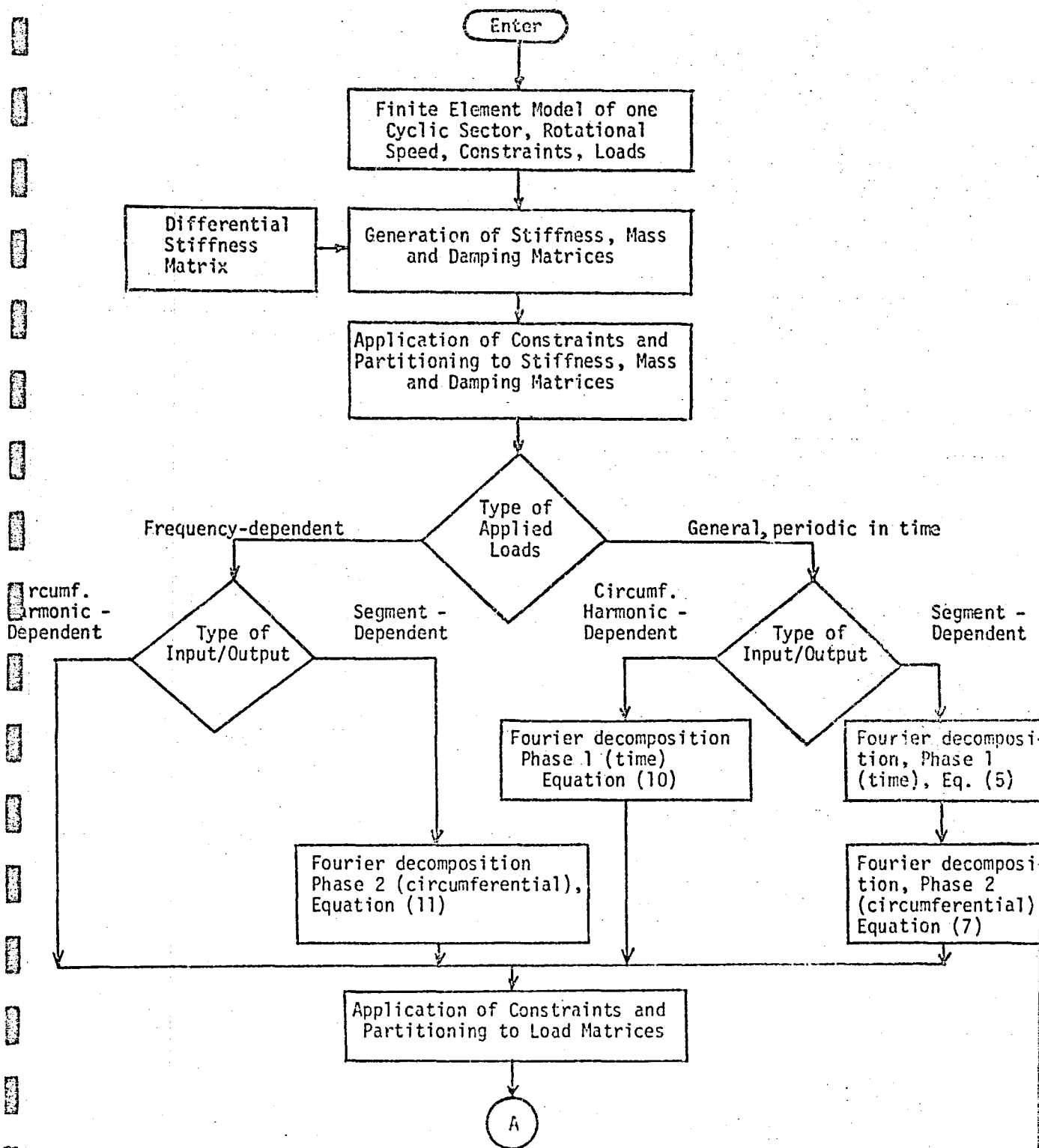


FIGURE 1: Overall Flowchart of Forced Vibration Analysis of Rotating Cyclic Structures

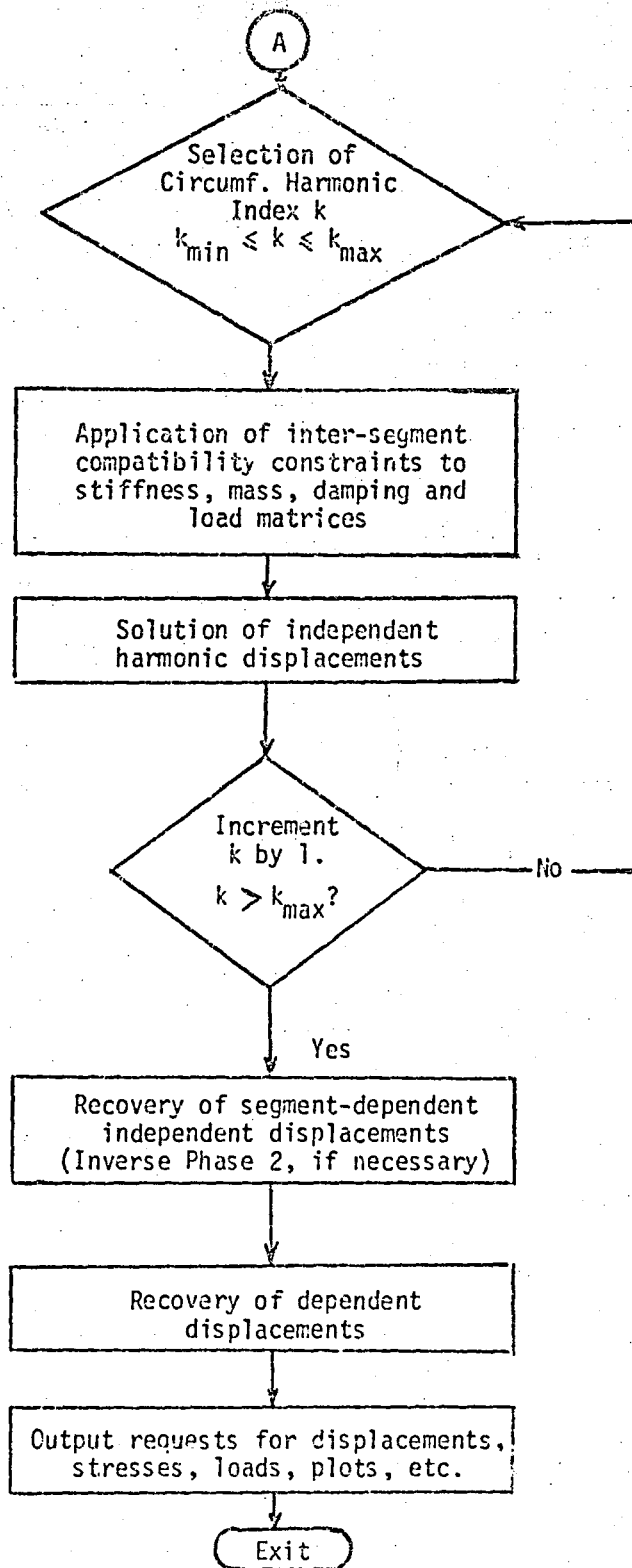


FIGURE 1. (Concluded)

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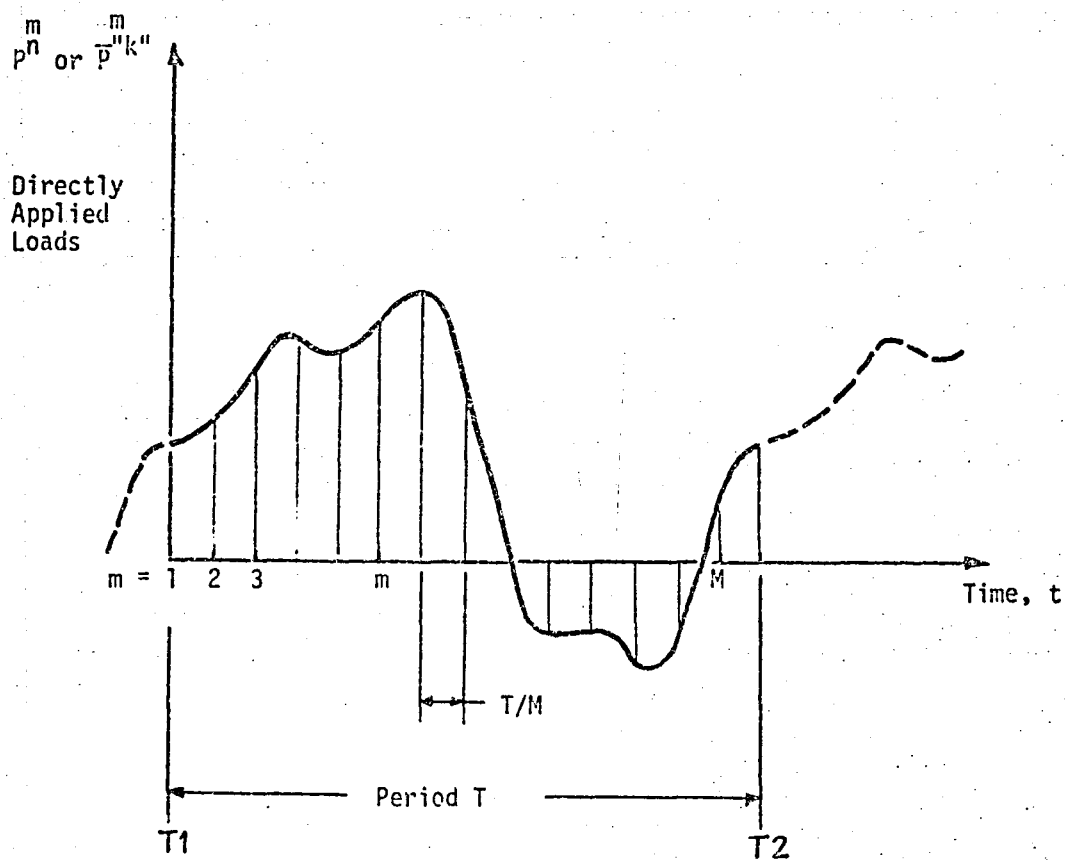


Figure 2: Directly Applied Periodic Loads Specified as Functions of Time

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^k , ($m = 1, 2, \dots, M$), 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 9.3-9, 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 ($\neq 1$) and KMAX ($\geq 0, \leq \text{NSEGS}/2$ for even NSEGS, $\leq (\text{NSEGS}-1)/2$ 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,

= $1 + 2 \cdot \text{KMAX}$, if $0 < \text{KMAX} \leq (\text{NSEGS}-1)/2$, NSEGS odd,

= $1 + 2 \cdot \text{KMAX}$, if $0 < \text{KMAX} \leq (\text{NSEGS}-2)/2$ 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, 1c and 1s as applicable.

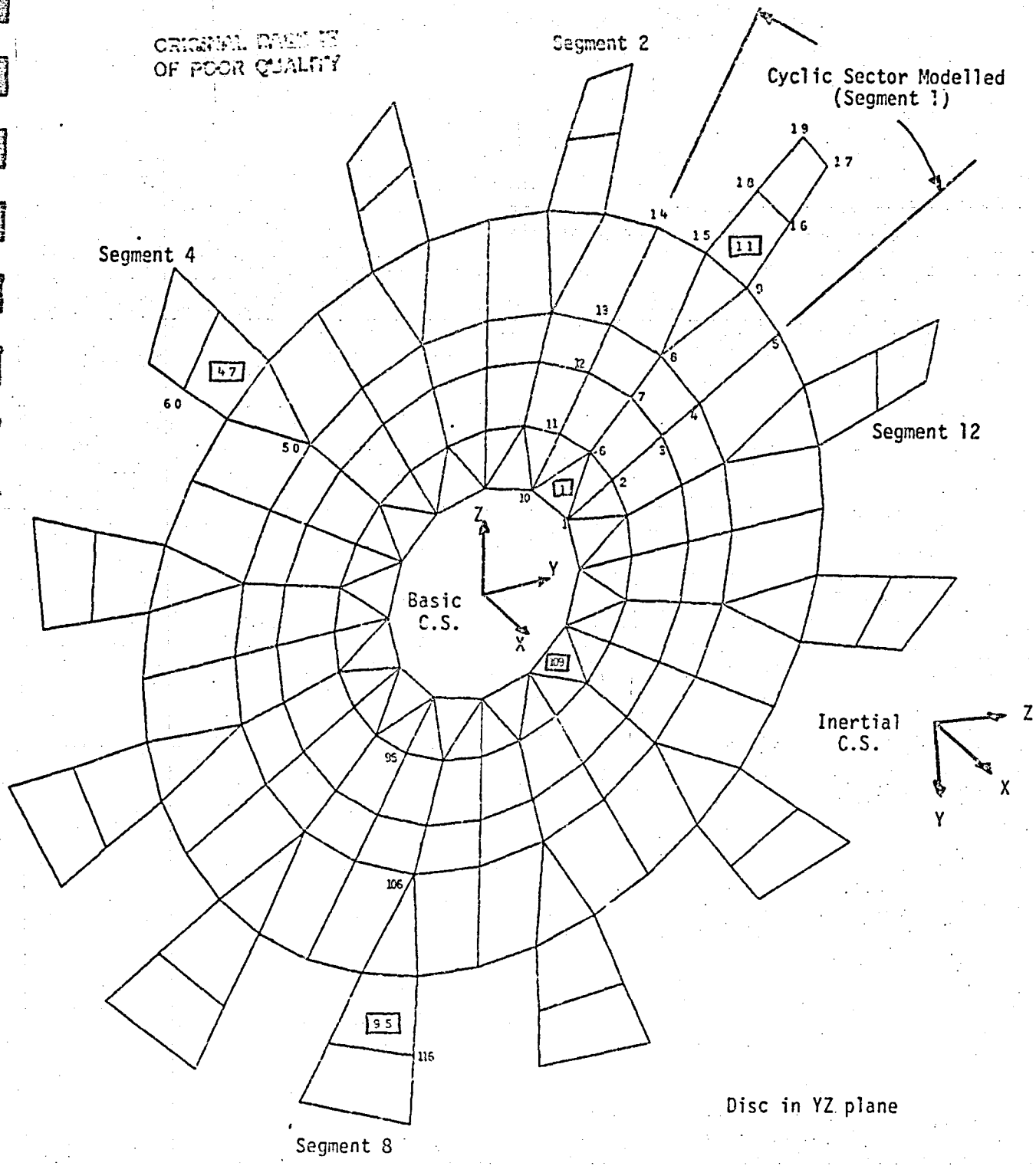


Figure 1: NASTRAN Model of the 12-Bladed Disc

2.4 Rigid Format Description

2.4.1 Rigid Format Alters to Displacement SOL 8

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*****  
$  
$ 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 CYCLO 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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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

- \$ 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. CYCLO - REQUIRED - THE INTEGER VALUE OF THIS PARAMETER
\$ SPECIFIES THE FORM OF THE INPUT AND OUTPUT DATA.
\$ A VALUE OF 61 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 TABLED BULK DATA CARDS WHICH DEFINE THE
\$ BXPTID COMPONENTS OF THE BASE ACCELERATION VECTOR. THE

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NASTRAN EXECUTIVE CONTROL DECK ECH

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$$$
ALTER 3 $
FILE      UXVF=APPEND/PDT=APPEND/PD=APPEND $
$ PERFORM INITIAL ERROR CHECKS ON NSEGS AND KMAX.
COND     ERRRC1,NSEGS $ IF USER HAS NOT SPECIFIED NSEGS.
COND     ERRRC1,KMAX $ IF USER HAS NOT SPECIFIED KMAX.
PARAM    //C,N,EQ //V,N,CYCIERR //V,Y,CYCIU=0 //C,N,0 $
COND     ERRRC1,CYCIERR $ 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     ERRRC1,KMAXERR $ IF KMAX .GT. NSEGS/2
$ SET DEFAULTS FOR PARAMETERS.
PARAM    //C,N,NOP //V,Y,NOKPRT=01 //V,Y,LGKAD=-1 $
$ CALCULATE OMEGA, 2*OMEGA AND OMEGA**2 FROM RPS. SET DEFAULT RPS.
PARAM    //C,N,MPY //V,N,OMEGA //V,Y,RPS=0.0 //C,N,0.283185 $
PARAM    //C,N,MPY //V,N,OMEGA2 //C,N,2.0 //V,N,OMEGA $
PARAM    //C,N,MPY //V,N,OMEGASQR //V,N,OMEGA //V,N,OMEGA $
$ GENERATE NOKPS FLAG IF RPS IS ZERO.
PARAM    //C,N,EW //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,CCUPMASS=-1 $
COND     ERRRC2,NOLUMP $
ALTER 21,21 $ ADD SLT TO OUTPUT FOR IRLG.
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 MSG2.
PARAM    //C,N,MPY //V,N,NSKIP //C,N,0 //C,N,0 $
GP4      CASECC,GEOM4,EQEXIN,OPDT,BGPDT,CSTM/RG,YS,USER,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,NCL/S,N,NDA/C,Y,ASETOUT/S,Y,AUTUSPC $
PURGE    GM,GM0/MPCF1/GC,GCD/OMIT/KFS,PSF,CPC/SINGLE $
CHKPNT   GM,GM0,RG,GC,GCD,KFS,PSF,CPC,USER,YS $
$ SUPORT BULK DATA IS NOT ALLOWED.
PARAM    //C,N,NOT //V,N,REACDATA //V,N,REACT $
COND     ERRRC3,REACDATA $
$ EXECUTE DPD NOW SO CHECKS CAN BE MADE. ADD IRL TO OUTPUT DATA BLOCKS.
DPL      DYNAMICS,GPL,SIL,USER / GPLD,SILD,USERD,TFPOOL,DLT,PSDL,FRL,
IRL,,EODYN / V,N,LUSET/S,N,LUSETD/V,N,NOTFL/S,N,NOULT/
S,N,NOPSDL/S,N,NOFRL/V,N,NOHLFT/S,N,NUTRL/V,N,NCEEP/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,NUTRL $
COND     ERRRC5,FTERR $ NO FREQ OR TSTEP BULK DATA.
$ ONLY FREQUENCY OR TSTEP IS ALLOWED IN THE CASE CONTROL
PARAM    CASECC //C,N,DTI //C,N,1 //C,N,14 //V,N,FREQSET $
PARAM    CASECC //C,N,DTI //C,N,1 //C,N,38 //V,N,TIMESSET $
PARAM    //C,N,MPY //V,N,FRETIME //V,N,FREQSET //V,N,TIMESSET $

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PARAM //C,N,NOT /V,N,PTERR1 /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,TIMESSET /C,N,0 $
COND ERRORC6,PTERR1 $ 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 CYC22 MODULE.
GPCYC GEOM4,EQDYN,USED /CYCDD /V,N,CTYPE=ROT /S,N,NOGU $
COND ERRORC1,NOGC $
CHKPNT CYCDD $
ALTER 32 $
$ PRE-PURGE DATA BLOCKS THAT WILL NOT BE GENERATED.
PARAM //C,N,UR /V,N,NOBMI /V,N,NOMGG /V,N,NORPS $
PURGE BIGG,MIGG /NOBMI $
PURGL M2GG,M2BASEXG /NOMGG $
ALTER 35 $
$ GENERATE DATA BLOCKS FRLX, BIGG, MIGG, M2GG AND BASEXG.
$ GENERATE PARAMETERS FKMAX AND NCBASEX.
DUMMOD1 CASECC,BGPD1,CSTM,DIT,FRL,MGG,, / FRLX,BIGG,MIGG,
M2GG,BASEXG,PDZER0,, /V,N,NUMGG/V,Y,CYCIC/V,Y,NSEGS/
V,Y,KMAX/S,N,FKMAX/V,Y,BXTID=-1/V,Y,BXPTID=-1/
V,Y,SYTID=-1/V,Y,BYPTID=-1/V,Y,BZTID=-1/
V,Y,BZPTID=-1/S,N,NCBASEX/V,N,NOFREQ/V,N,OMEGA $
PARAML FRLX //C,N,PRESNCE ///V,N,NOFRLX $
COND LBLFRLX,NOFRLX $
EQUIV FRLX,FRL $
LABEL LBLFRLX $
CHKPNT FRL,BIGG,MIGG,M2GG,BASEXG $
ALTER 42 $
PARAM //C,N,ADD /V,N,NOBGG /V,N,NOBMI /C,N,0 $ RESET NOBGG.
ALTER 52 $
$ REDEFINE BGG AND KGG.
COND LBL11A,NOBMI $
PARAMR //C,N,COMPLEX // V,N,OMEGA2 / C,N,0.0 / V,N,CMLX1 $
PARAMR //C,N,SLB / V,N,MCMEGASQ / C,N,0.0 / V,N,OMEGASQ $
PARAMR //C,N,COMPLEX // V,N,MOMEGASQ / C,N,0.0 / V,N,CMLX2 $
ADD BGG,BIGG / BGG1 / C,N,(1.0,0.0) / V,N,CMLX1 $
EQUIV BGG1,BGG $
ADD KGG,MIGG / KGG1 / C,N,(1.0,0.0) / V,N,CMLX2 $
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 LKAD FOR FREQ OR TRAN.
PARAM //C,N,AND/V,N,KDEKA/V,N,NOUE/V,N,NOK2PP $
COND LKAD1,LKAD $ BRANCH IN NOT FRECKESP.
ALTER 115 $ SLE ALTER 114 COMMENT.
JUMP LKAD2 $
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LABEL LGKAD1 \$
EQUIV M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEHA/
 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,GU,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
 GUD,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,NUM2PP/
 V,N,NUB2PP/V,N,MPCF1/V,N,SINGLE/V,N,OMIT/V,N,NOUE/V,N,NUK4GG/
 V,N,NOBGG/V,N,KOEK2/C,N,-1 \$
ALTER 118 \$ SEE ALTER 114 COMMENT.
COND LCKAD3,LGKAD \$ BRANCH IF NOT FREERESP.
ALTER 119 \$ SEE ALTER 114 COMMENT.
JUMP LCKAD4 \$
LABEL LCKAD3 \$
EQUIV B2DD,BDD/NOGPD1/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,REPEAT /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 TRLGLGOP \$
CASE CASLCC,/CASEYY/C,N,TRAN/S,N,REPEAT/S,N,NOLUCPI \$
CHKPNT CASLYY \$
PARAM //C,N,MPY /V,N,NCOL /C,N,0 /C,N,1 \$
TRLG CASLYY,USETD,DLT,SLT,BGPD1,SIL,CSTM,TRL,DIT,GMD,GUD,,EST,MGG/
 ,PLT1,PDI,,TCL/ V,N,NCSET/S,N,PDEPDU/V,N,NCCL \$
SDR1 TRL,PDI1,,,,,, / ,PDI /V,N,APPFLG/C,N,DYNAMICS \$
SDR1 TRL,PDI1,,,,,, / ,PD /V,N,APPFLG/C,N,DYNAMICS \$
PARAM //C,N,ADD /V,N,APPFLG /V,N,APPFLG /C,N,1 \$ APPFLG=APPFLG1.
COND TRLGCONE,REPEAT \$
KEPI TRLGLOOP,IOC \$
JUMP ERRGR3 \$
LABEL TRLGCONE \$
CHKPNT PCT,PD,TOL \$
EQUIV PC,PDT/PLEPDD \$
CHKPNT PCT \$
DJMMOD2 TOL,,,,,, / FRLZ,FOLZ,REORDER1,REORDER2,,,, /
 V,Y,NSEGS/V,Y,CYCIG/S,Y,LMAX=-1/V,N,FKMAX/
 S,N,FLMAX/S,N,NTSTEPS/S,N,NORC1/S,N,NORC2 \$
EQUIV FRLZ,FRL // FOLZ,FCL \$
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, GCD, DIT, / PPF, PSF, PDF, FOL, PHEDAM /  
          C, N, DIRECT / V, N, FREQU / C, N, FREQ $  
CCND      LBLFRLX1, NOFRLX $ ZERO OUT LOAD COLUMNS IF FRLX WAS GENERATED.  
MPYAD     PPF, PDZERU, / PPFX / C, N, 0 $  
LQIIV     PPFX, PPF $  
LABEL     LBLFRLX1 $  
$ FORM NEW LOADS.  
CCND      LBLFRL1, NOBASEX $  
MPYAD     M2GC, BASEXG, / M2BASEXG / C, N, 0 $  
ADD       PPF, M2BASEXG / PPF1 / C, N, (1.0, 0.0) / C, N, (-1.0, 0.0) $  
EQIIV     PPF1, PPF $  
CCND      LBLBASE1, NOSET $  
SSG2      USETD, GMD, YS, KFS, GOD, PPF / , PODUM1, PSF1, PDF1 $  
EQIIV     PSF1, PSF // PDF1, PDF $  
LABEL     LBLBASE1 $  
LABEL     LBLFRL1 $  
EQIIV     PPF, PDF / NOSLT $  
CHKPNT    PPF, PSF, PDF, FOL $  
$ LOADS ARE FREQUENCY-DEPENDENT  
$ PERFORM CYCLIC TRANSFORMATION ON LOADS IF CYCIC=&1.  
PARAM     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  
EQIIV     PDF, PPF / CYCIC $  
CCND      LBLPDONE, CYCIC $  
$ CALCULATE THE NUMBER OF LOADS FOR CYCIC=1.  
PARAM     // C, N, DIV / V, N, NLOAD / V, N, PDFCOLS / V, Y, NSEGS $ NLOAD = NF / NSEGS  
CYCT1     PDF / PPF, GYCF1 / V, N, CTYPER / C, N, FORE / V, Y, NSEGS=-1 /  
          V, Y, KMAX=-1 / V, N, NLOAD / S, N, NCGO $  
CCND      ERRORC1, NCGO $  
CHKPNT    PPF $  
JUMP      LBLPDONE $  
LABEL     LBLFRL2 $  
$ LOADS ARE TIME-DEPENDENT  
PARAM     // C, N, NCT / V, N, NOTCYCIC / V, Y, CYCIC $  
$ BRANCH DEPENDING ON VALUE OF CYCIC  
CCND      LBLTRL2, NOTCYCIC $  
$ CYCIC=-1  
EQIIV     PDT, PDTRZ1 / NURC1 $  
CCND      LBLK01A, NURC1 $  
MPYAD     PDT, REORDER1, / PDTRZ1 / C, N, 0 $  
LABEL     LBLK01A $  
CYCT1     PDTRZ1 / PXTKZ1, GYCF2 / V, N, CTYPER / C, N, FORE / V, N, NTSTEPS /  
          V, Y, LMAX / V, N, FKMAX / S, N, NCGO $  
CCND      ERRORC1, NCGO $  
CHKPNT    PXTKZ1 $  
EQIIV     PXTKZ1, PPFZ1 / NURD2 $  
CCND      LBLK02A, NURD2 $  
MPYAD     PXTKZ1, REORDER2, / PPFZ1 / C, N, 0 $  
LABEL     LBLK02A $
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EQUIV    PXFZ1,PXF1 $
CHKPNT   PXF1 $
JUMP     LBLTRL3 $
LABEL    LBLTRL2 $
$ CYCLC = 61
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,NOGC $
COND     ERRRC1,NOGC $
CHKPNT   PXTRZ2 $
EQUIV    PXTRZ2,PXTR2/NURD2 $
COND     LBLR02B,NURD2 $
MPYAD    PXTRZ2,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,NOGC $
COND     ERRRC1,NOGC $
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 FREQRSP 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 $ NLCAD = FLMAX
LABEL    LBLPDONE $
PARAM    //C,N,ADD /V,N,KINDEX /V,Y,KMIN=0 /C,N,0 $ INITIALIZE 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,,,PAF,,, /,,,PKFZ,,, / C,N,FORE/V,Y,NSEGS/
          V,N,KMINV/V,N,CYC SEQ/V,N,NLCAD/S,N,NOGC $
COND     ERRRC1,NOGC $
ADD      PKFZ, / UKVFZ / C,N,(0.0,0.0) $
CYCT2    CYCDD,,,UKVFZ,,, /,,,UXVF,,, / C,N,BACK/V,Y,NSEGS/
          V,N,KMINV/V,N,CYC SEQ/V,N,NLCAD/S,N,NOGC $
COND     ERRRC1,NOGC $
PARAM    //C,N,ADD /V,N,KMINV /V,N,KMINV /C,N,1 $
KEPT     KMINLOOP,KMINL $
LABEL    NOKMINL $
$
JUMP     TOPCYC $
LABEL    TOPCYC $ LOOP ON KINDEX
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CCND      NOKPRT,NOKPRT $
PRTPARM   //C,N,0 /C,N,KINDEX $
LABEL     NOKPRT $
CYCT2     CYCDD,KDD,MDD,,, /KKKF,MKKF,,, /C,N,FCRE/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,,,PXFF,, /BKKF,,PKF,, / C,N,FCRE/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
FRKRD2    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      TLPCYC,1CC $
JUMP      ERROR3 $
LABEL     LCYC2 $
EQUIV     UXVF,UDVF / CYC10 $
CHKPNT    UDVF $
COND      LCYC3,CYC10 $ IF CYC10 .GE. 0 THEN TRANSFORM TO PHYSICAL.
CYCT1     UXVF / UDVF,LCYC3 / 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 / CYC10 $
COND      LCYC4,CYC10 $ IF CYC10 .GE. 0 THEN TRANSFORM TO PHYSICAL.
CYCT1     PXF / PDF2,LCYC4 / V,N,CTYPE/C,N,BACK/V,Y,NSEGS/V,Y,KMAX/
          V,N,NLOAD $
LABEL     LCYC4 $
$ IF LOADS W/LKE TIME-DEPENDENT THEN RECOVER PPF AND PSF FROM PXF.
SDK1      USETD,,PDF2,,,GDD,GMD,,, / PPFZ,, /C,N,1 /C,N,DYNAMICS $
SSG2      USETD,GMD,YS,XFS,GDD,,PPFZ / ,PCDUM,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       CASXX,EUDYN,USETD,UDVF,FOL,XYCDB,/UDVCI,/C,N,FREQRES/C,N,
          DIRECT/S,N,NSUR12/S,N,NCD/S,N,NUP/C,N,0 $
ALTER 140,140 $ USE FOL INSTEAD OF PPF TO GET OUTPUT FREQUENCY LIST.

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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

SURZ CASEXX,CSTM,MPT,JIT,EDDYN,SILD,; ,BGPPD,FLL,QPC,UPVC,EST,XYCOB,
PPF/UPPCI,OPPCI,OPVCI,DESCI,CEPCI,PUPVCI/C,N,FREQRESP/
S,N,NOSURT2 \$

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,CYCSTATIC \$
LABEL ERRORC2 \$ COUPLED MASS NOT ALLOWED.
PRTPARM //C,N,0 /C,Y,COUPPASS \$
JUMP FINIS \$

LABEL ERRORC3 \$ SUPRT BULK DATA NOT ALLOWED.
PRTPARM //C,N,-6 /C,N,CYCSTATIC \$
LABEL ERRORC4 \$ EPOINT BULK DATA NOT ALLOWED.
PRTPARM //C,N,0 /C,N,NQUE \$
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 \$

ENLALTER

FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES

2.4.2 DMAP Sequence for Forced Vibration Analysis of Rotating Cyclic Structures

```

OPTIONS IN EFFECT  GO      ERR=2  NDLIST  NODECK  NOREF  NOOSCAR

1  BEGIN          NO.8  FORCED VIBRATIONS OF ROTATING CYCLIC STRUCTURES - SERIES R
2  PKLCHK        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          ERRURC1,NSEGS $ IF USER HAS NOT SPECIFIED NSEGS.
6  COND          ERRURC1,KMAX $ IF USER HAS NOT SPECIFIED KMAX.
7  PARAM         //C,N,EQ /V,N,CYCIDERR /V,Y,CYCID=0 /C,N,0 $
8  COND          ERRURC1,CYCIDERR $ IF USER HAS NOT SPECIFIED CYCID.
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          ERRURC1,KMAXERR $ IF KMAX .GT. NSEGS/2
12 PARAM         //C,N,NUP /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,NURPS $
17 PARAM         //C,N,NOT /V,N,NOLUMP /V,Y,COUPMASS=-1 $
18 COND          ERRURC2,NOLUMP $
19 PARAM         //*MPY*/CARDNO/O/C $
20 GPL           GEUM1,GEUM2, /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,NOGPD T $
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 PLDT      PLTPAR,GPSETS,ELSETS,CASECC,BGPD T,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,GPIT / V,N,NOGRAV $
37 CHKPNT    SLT,GPIT $
38 TAIL      ECT,EPT,BGPD T,SIL,GPIT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,NOSIMP=
             -1/1/S,N,NOGENL=-1/S,N,GENEL $
39 PURGE     K4GG,GPST,CGPST,MGG,BGG,K4FF,K4AA,MNN,MFF,MAA,BNN,BFF,BAA,
             KGGX/NOSIMP/CGPST/GENEL $
40 PARAM     //C,N,MPY /V,N,NSKIP /C,N,0 /C,N,0 $
41 GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPD T,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,GCD/OMIT/KFS,PSF,QPC/SINGLE $
43 CHKPNT    GM,GMD,RG,GU,GCD,KFS,PSF,QPC,USET,YS $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
44 PARAM //C,N,NOT /V,N,REACDATA /V,N,REACT $
45 COND ERRORC3,REACDATA $
46 UPD DYNAMICS,GPL,SIL,USET / GPLD,SILD,USED,TFPCOL,OLT,PSDL,FRL,
    TRL,EQDYN / V,N,LUSET/S,N,LUSETD/V,N,NOTFL/S,N,NODLT/
    S,N,NGPSDL/S,N,NDFRL/V,N,NONLFT/S,N,NOTRL/V,N,NOEED/C,N,/
    S,N,NOUE $
47 PARAM //C,N,AND/V,N,FTERR /V,N,NCFRL /V,N,NOTRL $
48 COND ERRORC5,FTERR $ NC 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,TIMESSET $
51 PARAM //C,N,MPY /V,N,FREQTIME /V,N,FREQSET /V,N,TIMESSET $
52 PARAM //C,N,NOT /V,N,FTERR1 /V,N,FREQTIME $
53 PARAM //C,N,LE /V,N,NDFREQ /V,N,FREQSET /C,N,0 $
54 PARAM //C,N,LE /V,N,NOTIME /V,N,TIMESSET /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,NCUE $
57 COND ERRORC4,EXTRAPTS $
58 GPCYC GEUM4,EQDYN,USED /CYCDD /V,N,CTYPE=ROT /S,N,NOGO $
59 COND ERRORC1,NOGO $
60 CHKPNT CYCDD $
61 COND LBL1,NOUSIMP $
62 PARAM /**ADD*/NOKGGX/1/0 $
63 PARAM /**ADD*/NOBGG/1/0 $
64 PARAM /**ADD*/NOBGG=-1/1/0 $
65 PARAM /**ADD*/NOK4GG/1/0. $
66 EMG EST,CSTM,MPT,DIT,GEUM2, /KELM,KDICT,MELM,MDICT,BELM,BDICT/ S,
    N,NOKGGX/S,N,NOBGG/S,N,NOBGG/S,N,NOK4GG/ /C,Y,COUPMASS/C,Y,
    CPBAR/C,Y,CPRUD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIAL/C,Y,
```

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LEVEL 2.0 NASTRAN DMAP COMPILER -- SOURCE LISTING

67 COND CPTR IA2/C,Y,CPTUBE/C,Y,CPODPLT/C,Y,CPTRPLT/C,Y,CPTRBSC \$
LBLKGGX,NOKGGX \$

68 EMA GPECT,KDICT,KELM/KGGX,GPST \$

69 LABEL LBLKGGX \$

70 PARAM //C,N,OR /V,N,NOBML /V,N,NOMGG /V,N,NORPS \$

71 PURGE BIGG,MIGG /NOBML \$

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,BGPD,CSIM,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,NCFREQ/V,N,GPEGA \$

77 PARAML FRLX //C,N,PRESNCE ///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,BOICT,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 \$

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
99 PARAM //C,N,ADD /V,N,NOBGG /V,N,NOBML /C,N,0 $ RESET NOBGG.
90 PURGE BNN,BFF,BAA/NOBGG $
91 COND LBL1,GRDPNT $
92 COND ERROR4,NOBGG $
93 GPWG BGPDP,CSTM,EQEXIN,HGG/CGPHG/V,Y,GRDPNT=-1/C,Y,WT MASS $
94 DFP UGPWG,,,,,//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,NORM1 $
101 PARAMR //C,N,COMPLX // V,N,OMEGA2 / C,N,0.0 / V,N,CMLX1 $
102 PARAMR //C,N,SUB / V,N,OMEGASQ / C,N,0.0 / V,N,CEGASQR $
103 PARAMR //C,N,COMPLEX // V,N,OMEGASQ / C,N,0.0 / V,N,CMLX2 $
104 ADD BGG,BIGG / BGG1 / C,N,(1.0,0.0) / V,N,CMLX1 $
105 EQUIV BGG1,BGG $
106 ADD KGG,MIGG / KGG1 / C,N,(1.0,0.0) / V,N,CMLX2 $
107 EQUIV KGG1,KGG $
108 CHPNT BGG,KGG $
109 LABEL LBL11A
110 COND LBL4,GENEL $
111 COND LBL4,NOSIMP $
112 PARAM /*EQ*/GPSFLG/AUTOSPC/0 $
113 COND LBL4,GPSPFLG $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
114 GPSP      GPL,GPST,USE T,SIL/OGPST/S,N,NOGPST $
115 COND     LBL4,NOGPST $
116 JFP      OGPST,,,,,//S,N,CARDNO $
117 LABEL    LBL4 $
118 EQU IV   KGG,KNN/MPCF1/MGG,MNN/MPCF1/ BGG,BNN/MPCF1/K4GG,K4NN/MPCF1 $
119 COND     LBL2,MPCF1 $
120 MCE1     USET,RG/GM $
121 MCE2     USET,GM,KGG,MGG,BGG,K4GG/KNN,MNN,BNN,K4NN $
122 LABEL    LBL2 $
123 EQU IV   KNN,KFF/SINGLE/MNN,MFF/SINGLE/BNN,BFF/SINGLE/K4NN,K4FF/SINGLE $
124 COND     LBL3,SINGLE $
125 SCE1     USET,KNN,MNN,BNN,K4NN/KFF,KFS,,MFF,BFF,K4FF $
126 LABEL    LBL3 $
127 EQU IV   KFF,KAA/OMIT $
128 EQU IV   MFF,MAA/OMIT $
129 EQU IV   BFF,BAA/OMIT $
130 EQU IV   K4FF,K4AA/OMIT $
131 COND     LBL5,OMIT $
132 SMP 1    USET,KFF,,,/GO,KAA,KCC,LCO,,,,, $
133 COND     LBLM,NOMGG $
134 SMP 2    USET,GO,MFF/MAA $
135 LABEL    LBLM $
136 COND     LBLB,NOBGG $
137 SMP 2    USET,GO,BFF/BAA $
138 LABEL    LBLB $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
139 COND      LBL5,NOK4GG $
140 SMP2      USET,GO,K4FF/K4AA $
141 LABEL     LBL5 $
142 EQU IV    GO,GOD/NOUE/GH,GMD/NCLE $
143 PARAM     /*ADD*/NEVER/1/0 $
144 PARAM     /*MPY*/REPEATF/-1/1 $
145 BMG       MATPOOL,BGPD,T,EQEXIN,CSTM/BDPCCL/S,N,NCKBFL/S,N,NOABFL/S,N,
             MFACT $
146 PARAM     /*AND*/NOFL/NCABFL/NOKBFL $
147 PURGE     KBFL/NOKBFL/ ABFL/NCABFL $
148 COND      LBLFL3,NCFL $
149 MTRX IN   ,BUPOOL,EQDYN,,/ABFL,KBFL,/LUSETD/S,N,NOABFL/S,N,NOKBFL/O $
150 LABEL     LBLFL3 $
151 JUMP      LBL13 $
152 LABEL     LBL13 $
153 PURGE     QUDVC1,ULDVC2,XYPLTFA,UPPC1,GQPC1,GUPVC1,CESC1,DEFC1,UPPC1,
             QQPC2,QUPVC2,DESC2,DEFC2,XYPLTF,PSDF,AUTO,XYPLTR, K2PP,M2PP,
             B2PP,K2DD,M2DD,B2DD/NEVER $
154 CASE      CASECC,PSDL/CASEXX/*FREQ*/S,N,REPEATF/S,N,NOLOOP $
155 MTRX IN   CASEXX.MATPOOL,EQDYN,,TFPCOL/K2OPP,M2OPP,B2PP/LUSETD/S,N,
             NOK2OPP/S,N,NOM2OPP/S,N,NCB2PP $
156 PARAM     /*AND*/NOM2PP/NCABFL/NOM2OPP $
157 PARAM     /*AND*/NOK2PP/NOFL /NCK2OPP $
158 EQU IV    M2OPP,M2PP/NOABFL $
159 ADD5      ABFL,KBFL,K2OPP,,/K2PP/(-1.0,0.0) $
160 COND      LBLFL2,NCABFL $
161 TRNSP     ABFL/ABFLT $
```

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
162 ADD      ABFLT,M2DDP/M2PP/MFACT $
163 LABEL    LBLFL2 $
164 PARAM    /*AND*/BDEBA/NOUE/NOB2PP $
165 PARAM    /*AND*/KDEK2/NOGENL/NOSIMP $
166 PARAM    /*AND*/MDEMA/NOUE/NCM2PP $
167 PURGE    K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $
168 PARAM    //C,N,AND/V,N,KDEKA/V,N,NOUE/V,N,NCK2PP $
169 COND     LGKAD1,LGKAD $  BRANCH IN NOT FREQRESP.
170 EQU IV   M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/BAA,
            BDD/BDEBA $
171 JUMP     LGKAD2 $
172 LABEL    LGKAD1 $
173 EQU IV   M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/
            KAA,KDD/KDEKA $
174 CHK PNT  K2PP,M2PP,B2PP,K2DD,M2DD,B2DD,KDD,MDD $
175 LABEL    LGKAD2 $
176 COND     LBL18,NOGPD $
177 GKAD     USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
            GDD,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 EQU IV   B2DD,BDD/NOBGG/M2DD,MDD/NOSIMP/K2DD,KDD/KDEK2 $
181 JUMP     LGKAD4 $
182 LABEL    LGKAD3 $
183 EQU IV   B2DD,BDD/NOGPD/M2DD,MDD/NCIMP/K2DD,KDD/KDEK2 $
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
184 LABEL      LGKAD4 $
185 COND       LBLTRL1,NOTIME $
186 PARAM      //C,N,MPY /V,N,REPEAT /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,REPEAT/S,N,NCLOOPI $
191 CHKPNT     CASEYY $
192 PARAM      //C,N,MPY /V,N,NCOL /C,N,0 /C,N,1 $
193 TRLG       CASEYY,USED,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GOD,,EST,MGG/
,,PDT1,PD1,,TOL/ V,N,NOSET/S,N,PDEPDC/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,REPEAT $
198 REPT       TRLGLOOP,100 $
199 JUMP       ERROR3 $
200 LABEL      TRLGDONE $
201 CHKPNT     PDT,PD,TOL $
202 EQUJ       PD,PDT/PDEPDC $
203 CHKPNT     PDT $
204 DUMMOO2    TOL,,,,,,,, / FRLZ,FOLZ,REORDER1,REORDER2,,,, /
V,Y,NSEGS/V,Y,CYCLIC/S,Y,LMAX=-1/V,N,FKMAX/
S,N,FLMAX/S,N,NTSTEPS/S,N,NGROL/S,N,NORD2 $
205 EQUJ       FRLZ,FRL // FOLZ,FCL $
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, GHD, GOD, DIT, / PPF, PSF, PDF, FOL, PHFDM /
              C, N, DIRECT / V, N, FREQ / C, N, FREQ $
210 COND      LBLFRLX1, NOFRLX $ ZERO OUT LOAD COLUMNS IF FRLX WAS GENERATED.
211 MPYAD     PPF, PDZERU, / PPFX / C, N, 0 $
212 EQJIV     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 EQJIV     PPF1, PPF $
218 COND      LBLBASE1, NOSET $
219 SSG2      USETD, GMD, YS, KFS, GCD, , PPF / , PODUM1, PSF1, PDF1 $
220 EQJIV     PSF1, PSF // PDF1, PDF $
221 LABEL      LBLBASE1 $
222 LABEL      LBLFRL1 $
223 EQJIV     PPF, PDF / NOSET $
224 CHKPNT    PPF, PSF, PDF, FOL $
225 PARAM     PDF // C, N, TRAILER / C, N, 1 / V, N, PDFCCLS $
226 PARAM     // C, N, DIV / V, N, NLOAD / V, N, PDFCCLS / V, N, FKMAX $ NLOAD = NF / FKMAX
227 EQUIV     PDF, PXF / CYCIC $
228 COND      LBLPDUNE, CYCID $
229 PARAM     // C, N, DIV / V, N, NLOAD / V, N, PDFCCLS / V, Y, NSEGS $ NLOAD = NF / NSEGS
230 CYCT1     PDF / PXF, GCYCF1 / V, N, CTYPE / C, N, FCRE / 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/NCROL $
238  COND   LBLRO1A,NORU1 $
239  MPYAD  POT,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   ERRURC1,NOGO $
243  CHKPNT  PXTRZ1 $
244  EQUIV  PXTRZ1,PXFZ1/NCRO2 $
245  COND   LBLPO2A,NORL2 $
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 /PXTZ2,GCYCF3 /V,N,CTYPE/C,N,FCRE/V,N,NTSTEPS/V,Y,LMAX/
V,Y,NSEGS/S,N,NOGO $
254  COND   ERRURC1,NOGO $
255  CHKPNT  PXTRZ2 $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

256 EQUIV PXTRZ2,PXTR2/NORO2 \$
257 COND LBLRO2B,NORO2 \$
258 MPYAD PXTRZ2,REORDER2, / PXTR2 /C,N,0 \$
259 LABEL LBLRO2B \$
260 CYCT1 PXTR2 / PXFZ2,GCYCF4 / V,N,CTYPE/C,N,FORE/V,Y,NSEGS/V,Y,KMAX/
V,N,FLMAX/S,N,ACGC \$
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,ACGC \$
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,ACGC \$
279 COND ERRORC1,NOGO \$

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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,KHIAL $
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,MOD,,, /KKKF,MKKF,,, /C,N,FORE/V,Y,NSEGS /
V,N,KINDEX/V,N,CYCSEQ=-1/V,N,NLOAD/S,N,NOGC $
289 COND ERRORC1,NOGU $
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,NLCAD/S,N,NOGO $
293 PARAM //C,N,SYST //C,N,58 /C,N,0 $ RESET MPYAD METHOD CONTROL.
294 COND ERRORC1,NOGC $
295 CHKPNT BKKF,PKF $
296 FRRD2 KKKF,BKKF,MKKF,,PKF,FCL / UKVF /C,N,0.0/C,N,0.0/C,N,-1.0 $
297 CHKPNT UKVF $
298 CYCT2 CYCDD,,,LKVF,, /,,UXVF,, /C,N,BACK/V,Y,NSEGS/V,N,KINDEX/
V,N,CYCSEQ/V,N,NLCAD/S,N,NOGC $
299 COND ERRORC1,NOGU $
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
```

LEVEL 2.0 NASTRAN DMAP COMPILER -- SOURCE LISTING

```
304 REPT      TOPCYC,100 $
305 JUMP      ERROR3 $
306 LABEL     LCYC2 $
307 EQUIV     UXVF,UDVF / CYC10 $
308 CHKPNT    UDFV $
309 COND      LCYC3,CYC10 $ IF CYC10 .GE. 0 THEN TRANSFORM TO PHYSICAL.
310 CYCT1     UXVF / UDFV,GCYCB1 / V,N,CTYPE/C,N,BACK/V,Y,NSEGS/V,Y,KMAX/
              V,N,NLOAD $
311 CHKPNT    JDFV $
312 LABEL     LCYC3 $
313 COND      LBLTRL4,NOTIME $
314 EQUIV     PXF,PDF2 / CYC10 $
315 COND      LCYC4,CYC10 $ IF CYC10 .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,,GDD,GMD,,, / PPFZ,, /C,N,1 /C,N,DYNAMICS $
319 SSG2      USETD,GMD,YS,KFS,GDD,,PPFZ / ,PCDUP,PSFZ,PLDUM $
320 EQUIV     PPFZ,PPF // PSFZ,PSF $
321 CHKPNT    PPF,PSF $
322 LABEL     LBLTRL4 $
323 VDR       CASEXX,EQDYN,USETD,UDVF,FLL,XYCDB,/OUDVC1,/C,N,FREQRESP/C,N,
              DIRECT/S,N,NOSORT2/S,N,NOD/S,N,NCP/C,N,0 $
324 COND      LBL15,NOD $
325 COND      LBL15A,NOSORT2 $
326 SDR3      OUDVC1,,,,,/OUDVC2,,,, $
327 OFF       OUDVC2,,,,,/S,N,CARDNC $
```

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LEVEL 2.0 NASTKAN DMAP COMPILER - SOURCE LISTING

```
328 XYTRAN  XYCDB, OUDVC 2, , , , /XYPLTFA/*FREQ*/ *DSET*/S, N, PFILE/S, N, CARDNO $
329 XYPLGT  XYPLTFA// $
330 JUMP    LBL15 $
331 LABEL  LBL15A $
332 OFP    OUDVC1, , , , //S, N, CARDNO $
333 LABEL  LBL15 $
334 COND   LBL20, NOP $
335 EQUIV  UDV, UPVC/NOA $
336 COND   LBL19, NOA $
337 SDR1   USETD, , UDV, , , GUD, 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, ODESC1, CEFC1, PUPVC1/C, N, FREQRESP/
S, N, NOSURT2 $
340 COND   LBL17, NOSURT2 $
341 SDR3   OPPC1, OQPC1, OUPVC1, ODESC1, DEFC1, /OPPC2, OQPC2, OUPVC2, ODESC2,
DEFC2, $
342 JFP    OPPC2, OQPC2, OUPVC2, CEFC2, ODESC2, //S, N, CARDNO $
343 XYTRAN  XYCDB, OPPC2, OQPC2, OUPVC2, ODESC2, CEFC2/XYPLTF/*FREQ*/ *PSET*/ S,
N, PFILE/S, N, CARDNO $
344 XYPLGT  XYPLTF// $
345 COND   LBL16, NOPSOL $
346 FANDM  XYCDB, DIT, PSDL, OUPVC2, OPPC2, OQPC2, ODESC2, DEFC2, CASEXX/PSDF, AUTU/
S, N, NORD $
347 COND   LBL16, NORD $
348 XYTRAN  XYCDB, PSDF, AUTU, , , /XYPLTR/*RAND*/ *PSET*/S, N, PFILE/ S, N,
CARDNO $
349 XYPLGT  XYPLTR// $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
350 JUMP      LBL16 $
351 LABEL     LBL17 $
352 JFP       OUPVCI,OPPCI,QQPCI,GEFCI,DESCI, //S,N,CARDNO $
353 LABEL     LBL16 $
354 COND      LBL20,JUMPPLOT $
355 PLOT      PLTPAR,UPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUPVCI, GPECT,
             QESC1/PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTF LG/ S,N,PFILE $
356 PRTMSG    PLOTX2// $
357 LABEL     LBL20 $
358 COND      FINIS,REPEATF $
359 REPT      LBL13,100 $
360 LABEL     ERROR3 $
361 PRTPARM   //-3/*DIRFRKD* $
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     ERRJRC2 $ COUPLED MASS NOT ALLOWED.
368 PRTPARM   //C,N,0 /C,Y,COUPPASS $
369 JUMP      FINIS $
370 LABEL     ERRJRC3 $ 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 $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
375 LABEL      ERRORC5 $  NEITHER FREQ OR TSTEP WERE IN BULK DATA DECK.
376 PRTPARM    //C,N,0 /C,N,NOFRL $
377 PRTPARM    //C,N,0 /C,N,NCTRL $
378 JUMP       FINIS $
379 LABEL      ERRORC6 $  BOTH FREQ AND TSTEP WERE SELECTED IN CASE CONTROL.
380 PRTPARM    //C,N,0 /C,N,NOFREQ $
381 PRTPARM    //C,N,0 /C,N,NOTIME $
382 JUMP       FINIS $
383 LABEL      FINIS $
384 END        :
```

FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES

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 $[K_{gg}^X]$ 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 $[BIGG_{gg}]$, centripetal coefficient matrix $[MIGG_{gg}]$, Base acceleration coefficient matrix $[M2GG_{gg}]$, Base acceleration matrix $[BASEXG_g^F]$ and load modification matrix, $[PDZERO_g^F]$, 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 $[K_{gg}^4]$.
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 $[K_{ng}^X]$ to $[K_{gg}]$ if no general elements.
97. Go to DMAP No. 99 if no general elements.
98. SMA3 adds general elements to $[K_{gg}^X]$ 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

$$[BG61_{gg}] = [B_{gg}] + (4 - .RPS) [BIGG_{gg}]$$

105. Equivalence $[BGG]_{gg}$ to $[B_{gg}]$.
106. ADD assembles the centripetal acceleration matrix into the stiffness matrix.
 $[KGG]_{gg} = [K_{gg}] - (2\pi \cdot RPS)^2 [MGG]_{gg}$
107. Equivalence $[KGG]_{gg}$ 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 $[K_{gg}^4]$ to $[K_{nn}^4]$ 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 $[R_g] = [K_m | R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.
121. MCE2 partitions stiffness, mass and damping matrices

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

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

and performs matrix reductions

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

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

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

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

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

124. Go to DMAP No. 126 if no single-point constraints.
125. SCE1 partitions out single-point constraints

$$\begin{aligned}
 [K_{nn}] &= \begin{bmatrix} K_{ff} & K_{fs} \\ K_{sf} & K_{ss} \end{bmatrix} & [M_{nn}] &= \begin{bmatrix} M_{ff} & M_{fs} \\ M_{sf} & M_{ss} \end{bmatrix} \\
 [B_{nn}] &= \begin{bmatrix} B_{ff} & B_{fs} \\ B_{sf} & B_{ss} \end{bmatrix} & \text{and } [K_{nn}^4] &= \begin{bmatrix} K_{ff}^4 & K_{fs}^4 \\ K_{sf}^4 & K_{ss}^4 \end{bmatrix}
 \end{aligned}$$

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 $[K_{ff}^4]$ to $[K_{aa}^4]$ if no omitted coordinates.
131. Go to DMAP No. 141 if no omitted coordinates.
132. SMP1 partitions constrained stiffness matrix

$$[k_{ff}] = \begin{bmatrix} K_{aa} & K_{ao} \\ K_{oa} & K_{oo} \end{bmatrix}$$

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

133. Go to DMAP No. 135 if no mass matrix.
134. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \begin{bmatrix} M_{aa} & M_{ao} \\ M_{oa} & M_{oo} \end{bmatrix}$$

and performs matrix reduction

$$[M_{aa}^1] = [M_{aa}] + [M_{ao}][G_o] + [M_{ao}G_o]^T + [G_o^T][M_{oo}][G_o]$$

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

137. SMP2 partitions constrained viscous damping matrix

$$[B_{ff}] = \begin{bmatrix} B_{aa} & | & B_{ao} \\ \hline B_{oa} & | & B_{oo} \end{bmatrix}$$

and performs reduction

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

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

140. SMP2 partitions constrained structural damping matrix

$$[K_{ff}^4] = \begin{bmatrix} K_{aa}^4 & | & K_{ao}^4 \\ \hline K_{oa}^4 & | & K_{oo}^4 \end{bmatrix}$$

and performs matrix reduction

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

142. Equivalence $[G_o]$ to $[G_o^d]$ and $[G_m]$ to $[G_m^d]$ 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.
14. MTRXIN generates fluid boundary matrices $[A_{b,fl}]$ and $[K_{b,fl}]$ if a fluid structure interface is defined. The matrix $[K_{b,fl}]$ 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, $[K_{pp}^{2d}]$, $[M_{pp}^{2d}]$ and $[B_{pp}^2]$.
158. Equivalence $[M_{pp}^{2d}]$ to $[M_{pp}^2]$ if no $[A_{b,fl}]$.
159. ADD5 adds $[K_{b,fl}]$ and $[K_{pp}^{2d}]$ and subtracts $[A_{b,fl}]$ from them to form $[K_{pp}^2]$.

160. Go to DMAP No. 163 if $[A_{b,fx}]$ is not defined.
161. Transpose $[A_{b,fx}]$ to obtain $[A_{b,fx}]^T$.
162. ADD assembles input matrix $[M_{pp}^2] = MFACT [A_{b,fx}]^T + [M_{pp}^{2d}]$.
169. Go to DMAP No. 172 if transient type GKAD matrices are to be generated.
170. Equivalence $[M_{pp}^2]$ to $[M_{dd}^2]$, $[B_{pp}^2]$ to $[B_{dd}^2]$ and $[K_{pp}^2]$ to $[K_{dd}^2]$ 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 $[M_{pp}^2]$ to $[M_{dd}^2]$, $[B_{pp}^2]$ to $[B_{dd}^2]$ and $[K_{pp}^2]$ to $[K_{dd}^2]$ 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, if parameter GKAD = FREQRESP.

$$[K_{dd}] = (1 + ig)[K_{dd}^1] + [K_{dd}^2] + i[K_{dd}^4],$$

$$[M_{dd}] = [M_{dd}^1] + [M_{dd}^2] \text{ and}$$

$$[B_{dd}] = [B_{dd}^1] + [B_{dd}^2].$$

Direct input matrices may be complex.

or

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

$$[K_{dd}] = [K_{dd}^1] + [K_{dd}^2],$$

$$[M_{dd}] = [M_{dd}^1] + [M_{dd}^2],$$

$$\text{and } [B_{dd}] = [B_{dd}^1] + [B_{dd}^2] + \frac{g}{\omega_3} [K_{dd}^1] + \frac{1}{\omega_4} [K_{dd}^4],$$

where

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

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

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

and

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

All matrices are real.

179. Go to DMAP No. 182 if transient type GKAD matrices were generated.
180. Equivalence $[K_{dd}^2]$ to $[K_{dd}]$ if all stiffness is Direct Matrix Input, $[M_{dd}^2]$ to $[M_{dd}]$ if all mass is Direct Matrix Input and $[B_{dd}^2]$ to $[B_{dd}]$ if all damping is Direct Matrix Input.
181. Go to DMAP No. 184.
183. Equivalence $[B_{dd}^2]$ to $[B_{dd}]$ if all damping is Direct Matrix Input, $[M_{dd}^2]$ to $[M_{dd}]$ if all mass is Direct Matrix Input and $[K_{dd}^2]$ to $[K_{dd}]$ if 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 the current loop.
193. TRLG generates matrices of loads versus time. $\{P1_d^t\}$ 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 $\{P1_d^t\}$ to $\{P_d^t\}$.
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 than 100 loops.
202. Equivalence $\{P_d\}$ to $\{P_d^t\}$ 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 loads and the loads due to base acceleration.

$$\{P1_p^f\} = \{P_p^f\} - \{H2BASEXS_g^f\}$$

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

217. Equivalence $\{P1_p^f\}$ to $\{P_p^f\}$.

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

219. SSG2 applies constraints to $\{P_p^f\}$.

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 $\{P_d^t\}$ 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 $\{P_d^t\}$.

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 $\{P_d^t\}$.

253. CYCT1 transforms loads on analysis points to symmetric 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 symmetric 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 $\{PXF2\}$.

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

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

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 $\{UV_Z^f\} = \{PZ_k^f\} * 0.0$.

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 $\{P^f\}$ to $\{P_d^f\}$ 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.

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- 334. Go to DMAP No. 357 if no calculation 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

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

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

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

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

- 339. SDR2 calculates element forces ($\emptyset EFC1$) and stresses ($\emptyset ESC1$) and prepares load vectors ($\emptyset PPC1$), displacement vectors ($\emptyset UPVC1$), and single-point forces of constraint ($\emptyset QPC1$) 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. $\emptyset FP$ 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. XYPL $\emptyset T$ 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 (AUT \emptyset) using the previously calculated frequency response.
- 347. Go to DMAP No. 353 if no RANDOM calculations requested.
- 348. XYTRAN prepares the input for requested X-Y plots of the RANDOM output.
- 349. XYPL $\emptyset T$ 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 system 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 RANDOM RESPONSE ERROR MESSAGE NO. 3 - ATTEMPT TO EXECUTE MORE THAN 100 LOOPS.
364. DIRECT FREQUENCY AND RANDOM RESPONSE ERROR MESSAGE NO. 4 - MASS MATRIX REQUIRED FOR WEIGHT AND BALANCE CALCULATIONS.
366. STATICS WITH CYCLIC SYMMETRY ERROR MESSAGE NO. 7 - CYCLIC SYMMETRY DATA ERROR.
368. Coupled mass is not allowed - Print parameter COUPMASS.
371. STATICS WITH CYCLIC SYMMETRY ERROR MESSAGE NO. 6 - FREE-BODY SUPPORTS NOT ALLOWED.
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 CYCIO 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 frequency (SORT1) or by point number or element number (SORT2), is available, either as real and imaginary parts or magnitude and phase angle ($0^\circ - 360^\circ$ lead), for the list of frequencies specified:

1. Displacements, velocities, and accelerations for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SOLUTION 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 SOLUTION 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 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.

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

1. GRDPNT - 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. WTMASS - 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. COUPMASS - 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 for use 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. CYCI0 - 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 symmetry as follows:
 - (1) R0T - 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. NLOAD - 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 TABLED 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

<u>Record</u>	<u>Word</u>	<u>Type</u>	<u>Item</u>
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 BIGG (MATRIX)

Description

[BIGG_{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

<u>Record</u>	<u>Word</u>	<u>Type</u>	<u>Item</u>
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

<u>Record</u>	<u>Word</u>	<u>Type</u>	<u>Item</u>
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 single 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: DUMMOD1

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, BIGG, 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)
BIGG - 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. BIGG 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 - 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 BIGG and MIGG 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 BIGG, MIGG and M2GG

Phase one begins with a request for open core and buffer allocation. If OMEGA=0.0 then BIGG and MIGG 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 BIGG, MIGG 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 3×3 matrix $[M_i^1]$. If the grid point is not in the basic system then subroutine TRANSD calculates the 3×3 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 $[\bar{M}_i]$. The average of the three diagonal terms of $[\bar{M}_i]$ is then used to form $[\bar{B}T_i]$, $[\bar{M}T_i]$ and $[\bar{M}2_i]$. These three submatrices are then transformed back to the global coordinate system, if necessary. The 3×3 matrices $[\bar{B}T_i]$, $[\bar{M}T_i]$ and $[\bar{M}2_i]$ are then packed into the BIGG, MIGG and M2GG matrices.

(a)

$$[MGG]_{9 \times 9} = \begin{bmatrix} [M_1] & & & 0 \\ & [M_2] & & \\ & & \dots & \\ 0 & & & [M_n] \end{bmatrix}$$

where n = the total number of grid points.

where $[M_i]_{6 \times 6} = \begin{bmatrix} [M_i^1] & & \\ & \ddots & \\ & & [M_i^2] \end{bmatrix}$ for $i = 1, n$

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

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

$$[\bar{M}_i]_{3 \times 3} = [T_i] [M_i^1] [T_i]^T$$

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

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

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 BIGG

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

where $[B1_i]_{6 \times 6} = \begin{bmatrix} [B1_i^1] & & \\ & \ddots & \\ & & [0] \end{bmatrix}$

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

(e) Form M1GG

$$[M1GG]_{g \times g} = \begin{bmatrix} [M1_1] & & 0 \\ & [M1_2] & \\ 0 & & \ddots \\ & & & [M1_n^2] \end{bmatrix}$$



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where

$$[M1_i]_{6 \times 6} = \begin{bmatrix} [M1_i] & & \\ & & \\ & & \\ & & \\ & & \\ & & [0] \end{bmatrix}$$

and

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

(f) Form M2GG

$$[M2GG]_{9 \times 9} = \begin{bmatrix} [M2_1] & & & 0 \\ & [M2_2] & & \\ & & \dots & \\ 0 & & & [M2_n] \end{bmatrix}$$

where

$$[M2_i]_{6 \times 6} = \begin{bmatrix} [M2_i] & & \\ & & \\ & & \\ & & \\ & & \\ & & [0] \end{bmatrix}$$

and

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

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 or 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 $\omega_1 = 0.0$, 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 DUM01E to sort it in descending order. DUM01E 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 DUM01A, DUM01B, DUM01C and DUM01D are used to generate data block BASEXG. Routine DUM01A 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 DUM01B is called to generate the BASE table if the original FRL frequency list was not expanded, see phase two, otherwise routine DUM01C is called. Routine DUM01D 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 $\ddot{X}_0(f_i)$, $\theta_x(f_i)$, $\ddot{Y}_0(f_i)$, $\theta_y(f_i)$, $\ddot{Z}_0(f_i)$, $\theta_z(f_i)$ 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}_0 , \ddot{Y}_0 and \ddot{Z}_0 are magnitudes in L7-2 units while θ_x , θ_y and θ_z are phase angles in degrees.

(b) Define control flag MODFRL.

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).

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

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

$$[BASE]_{3 \times NF} = \{ \{ \text{Base}(f_1) \}_{3 \times 1} \cdot \dots \cdot \{ \text{Base}(f_{NF}) \}_{3 \times 1} \}$$

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

$$\{BASE(f_i)\}_{3 \times 1} = \begin{Bmatrix} \ddot{X}_0(f_i) \cdot e^{i\theta_x(f_i)} \\ \ddot{Y}_0(f_i) \cdot e^{i\theta_y(f_i)} \\ \ddot{Z}_0(f_i) \cdot e^{i\theta_z(f_i)} \end{Bmatrix}_{3 \times 1}$$

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

$$[BASE]_{3 \times NFX} = [BASE(f_1)] [BASE(f_2)] \dots [BASE(f_{NF})]$$

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

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

(e.1) If $\omega_i = 0.0$, then $[BASE(f_i)]_{3 \times 2}$ is defined as follows:

$$[BASE(f_i)]_{3 \times 2} = \begin{bmatrix} A & 0 \\ 0 & B \\ 0 & C \end{bmatrix}$$

where

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

$$A = \ddot{X}_0(f_i) \cdot e^{i\theta_x(f_i)}$$

$$B = \ddot{Y}_0(f_i) \cdot \cos(\theta_y(f_i)) - i \cdot SGN \cdot \ddot{Z}_0(f_i) \cdot \cos(\theta_z(f_i))$$

$$C = \ddot{Z}_0(f_i) \cdot \cos(\theta_z(f_i)) + i \cdot SGN \cdot \ddot{Y}_0(f_i) \cdot \cos(\theta_y(f_i))$$

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

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

where

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

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

and

$$A = \ddot{X}_0(f_i) \cdot e^{i\theta_x(f_i)}$$

$$B = 0.5 \cdot \left[\ddot{Y}_0(f_i) \cdot e^{i \cdot SGNA \cdot \theta_y(f_i)} - SGNA \cdot \ddot{Z}_0(f_i) \cdot e^{i \cdot SGNA \cdot (\theta_z(f_i) - SGNA \cdot \frac{\pi}{2})} \right]$$

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

$$D = 0.5 \cdot \left[\text{SGNA} \cdot \ddot{Y}_o(f_i) \cdot e^{i \cdot \text{SGNA} (\theta_y(f_i) - \text{SGNA} \cdot \pi/2)} + \ddot{Z}_o(f_i) \cdot e^{i \cdot \text{SGNA} \cdot \theta_z(f_i)} \right]$$

$$E = 0.5 \cdot \left[-\text{SGNB} \cdot \ddot{Y}_o(f_i) \cdot e^{i \cdot \text{SGNB} (\theta_y(f_i) - \text{SGNB} \cdot \pi/2)} + \ddot{Z}_o(f_i) \cdot e^{i \cdot \text{SGNB} \cdot \theta_z(f_i)} \right]$$

(f) Define the complex base acceleration matrix BASEXG of order $G \times (NF \cdot \text{FKMAX})$ as follows:

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

$$[\text{BASEXG}]_{g \times (NF \cdot \text{FKMAX})} = \left[\begin{array}{cccc} [\text{BASEXG}^1]_{g \times NF} & [\text{BASEXG}^2]_{g \times NF} & [\text{BASEXG}^3]_{g \times NF} & \dots & [\text{BASEXG}^{\text{FKMAX}}]_{g \times NF} \end{array} \right]$$

where

$$[\text{BASEXG}^i]_{g \times NF} = \left[\begin{array}{c} [\text{BASEX}^i]_{6 \times NF} \\ [\text{BASEX}^i]_{6 \times NF} \\ \vdots \\ [\text{BASEX}^i]_{6 \times NF} \end{array} \right] \quad \text{for } i = 1, 2 \text{ and } 3$$

and

$$[\text{BASEXG}^i]_{g \times NF} = [0] \quad \text{for } i = 4, 5, 6, \dots, \text{FKMAX}$$

NOTE: $[\text{BASEX}^i]$ 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.

$$[\text{BASEX}^1]_{6 \times NF} = \left[\begin{array}{cccc} \text{BASE}(1,1) & \text{BASE}(1,2) & \dots & \text{BASE}(1,NF) \\ 0 & 0 & & 0 \\ 0 & 0 & & 0 \\ 0 & 0 & & 0 \\ 0 & 0 & & 0 \\ 0 & 0 & & 0 \end{array} \right]$$

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

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

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: DUMODIA

1. Entry Point: DUMODIA
2. Purpose: To define and output the complex single precision base acceleration matrix BASEXG.
3. Calling Sequence: Call DUMODIA (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: DUM01E

1. Entry Point: DUM01E
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 DUM01E(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 Design Requirements

- 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:

Phase I

COMMON/DUM1XX/ 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

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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
Z(N2)	BASE1 MATRIX	(3*NFSX)*2
Z(N3)	COLUMN OF BASEXG	(G-set.)*2
	FREE	
Z(IBUF1)	DIT/BASEXG	GINO BUFFER+1

} Complex

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: DUMMOD2

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 LMAX, 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 S
```

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.

NOR01 - Output-integer-no default. NOR01=-1 if matrix REORDER1 is not generated, +1 otherwise.

NOR02 - Output-integer-no default. NOR02=-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 $i = 2, 4, 6, \dots, NFREQ$

and $FOL(j) = FOL(j-1)$ for $j = 3, 5, 7, \dots, NFREQ - 1$

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, $FRL(i) = FOL(i) * 2\pi$ for $i = 1, NFREQ$.

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

REORDER1 and REORDER2 are used for reordering columns of a matrix by post-multiplying the matrix whose columns are to be reordered. Routine DUM02A is called twice, once to generate and output REORDER1 and once to generate and output REORDER2. See the subroutine description of DUM02A for details.

3.2.2.8 Subroutines

DUMOD2 uses standard NASTRAN GINO routines and utility routines.

3.2.2.8.1 Subroutine Name: DUM02A

1. Entry Point: DUM02A
2. Purpose: To generate and output column reordering matrices REORDER1 and REORDER2 and to compute parameters NORO1 and NORO2.
3. Calling Sequence: CALL DUM02A(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(IBUFI)	TOL/FOL/FRL/REORDER	GINO BUFFER+1

3.2.2.10 Diagnostic Messages

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



3.3 OVERLAY CHARTS

3.3.1 IBM OVERLAY CHARTS

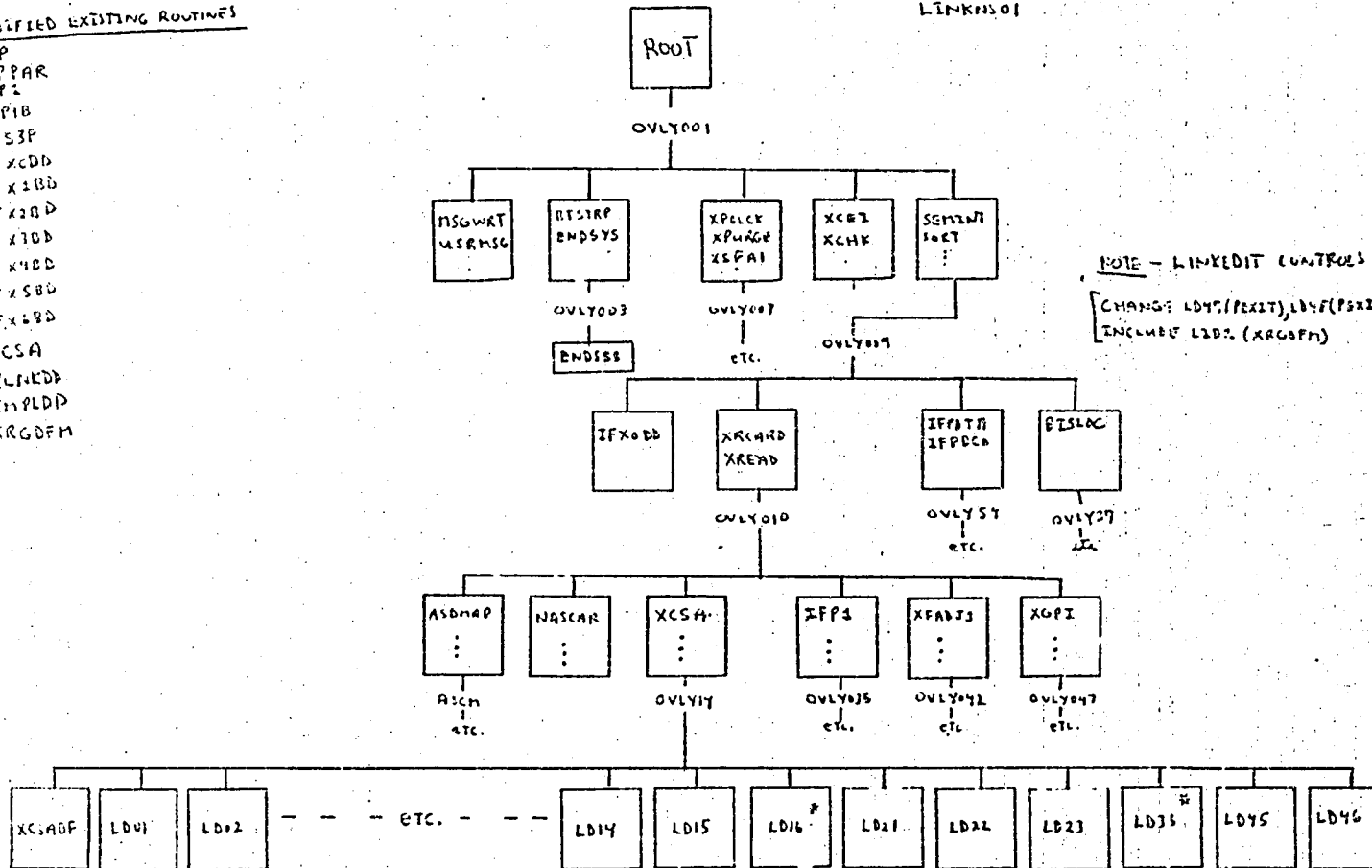
FOR NASTRAN LINKS

1, 6, 7, 9, 10, 11

CLASSIFIED EXISTING ROUTINES

ITP
 IFPPAR
 IFP2
 IFPIB
 IF53P
 IFXCDD
 IFX1BD
 IFX2BD
 IFX3BD
 IFX4BD
 IFX5BD
 IFX6BD
 XCSA
 XLNKDD
 XNPLDD
 XRGDFM

NASTRAN L17.7 (IBM)
 LINKL301



NOTE - LINKEDIT CONTROLS

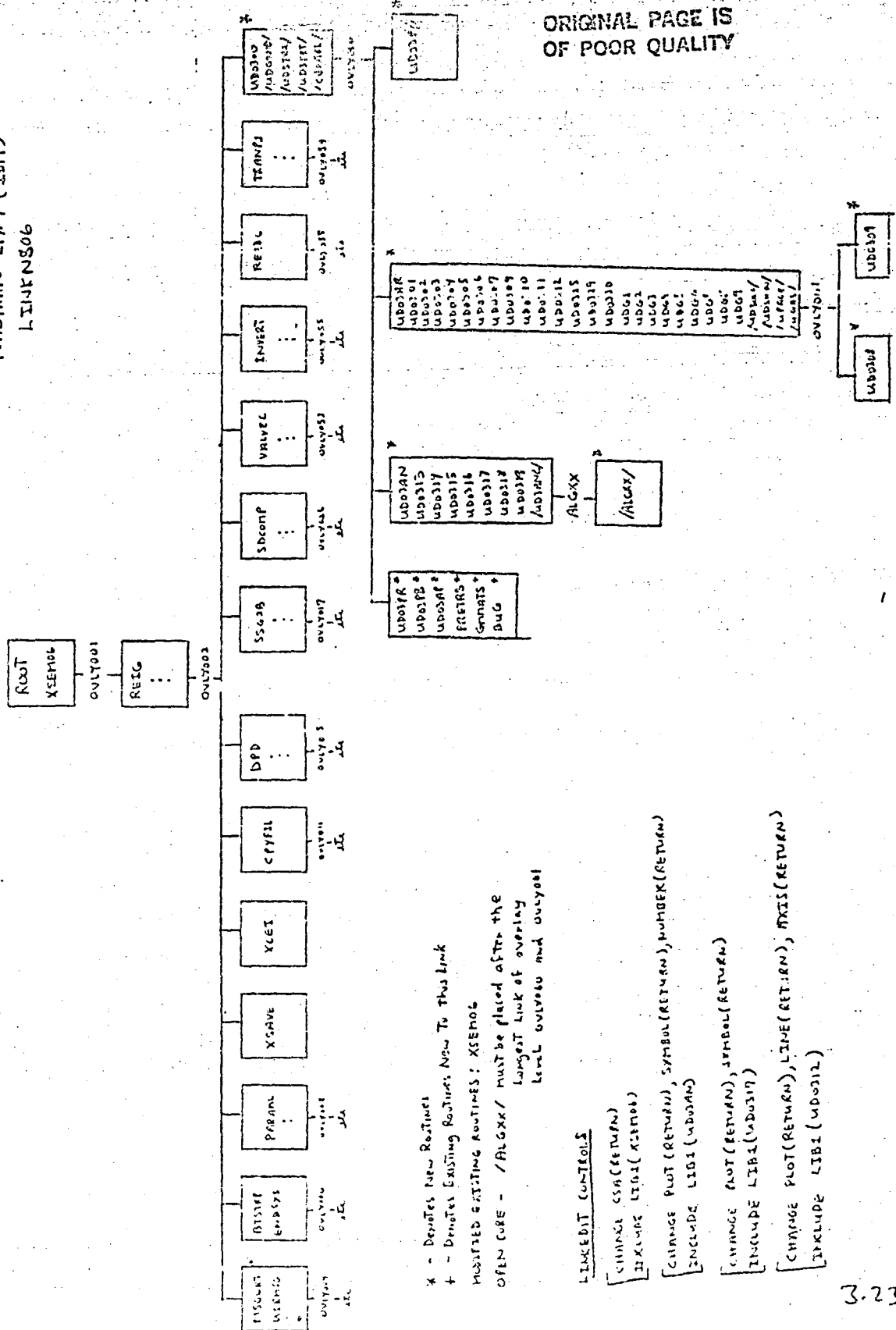
[CHANGE: LD01(PK1T), LD02(PK1T), LD03(PK1T), LD04(PK1T)
 INCLUDE: LD02 (XRGDFM)]

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* - Denotes New Routines

3.22

NASTRAN L17.7 (IBM)
LINKNS06



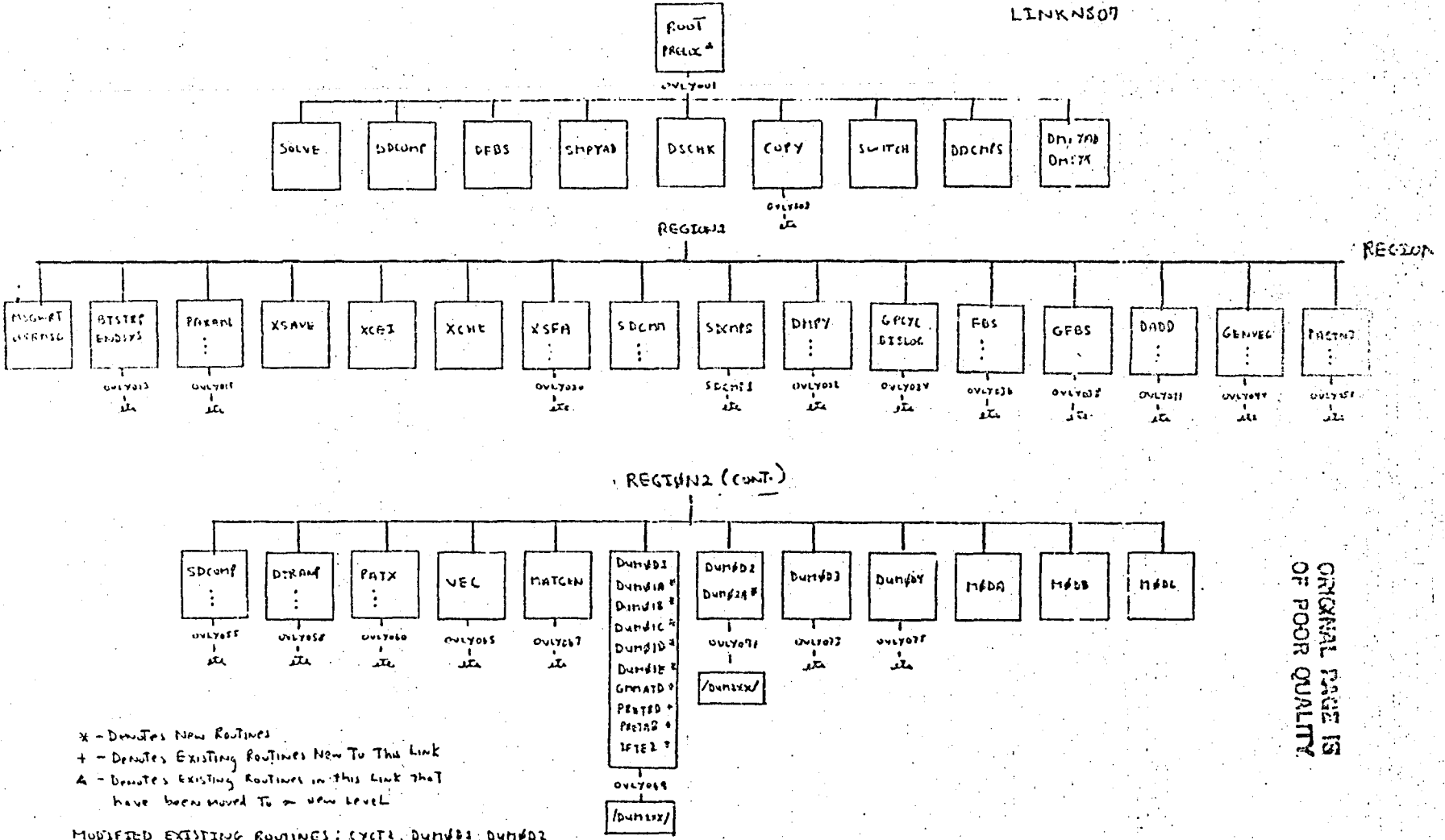
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* - Denotes New Routines
+ - Denotes Existing Routines Now To This Link
LISTED EXISTING ROUTINES: XSEMO6
OPEN CASE - /ALGX/ must be placed after the
largest link of overlying
level OUTL001 and OUTL002

LINKEDIT CONTROLS

- [CHANGE SSA(RETURN)
- [INCLUDE LIB1(XSEMO6)
- [CHANGE PLOT(RETURN), SYMBOL(RETURN), NUMBER(RETURN)
- [INCLUDE LIB1(UBD01A)
- [CHANGE PLOT(RETURN), SYMBOL(RETURN)
- [INCLUDE LIB1(UBD017)
- [CHANGE PLOT(RETURN), LINE(RETURN), AXIS(RETURN)
- [INCLUDE LIB1(UBD012)

NASTRAN L177 (IBH)
LINKN807



* - Denotes New Routines
 + - Denotes Existing Routines New To This Link
 A - Denotes Existing Routines In This Link That
 have been moved to a new level

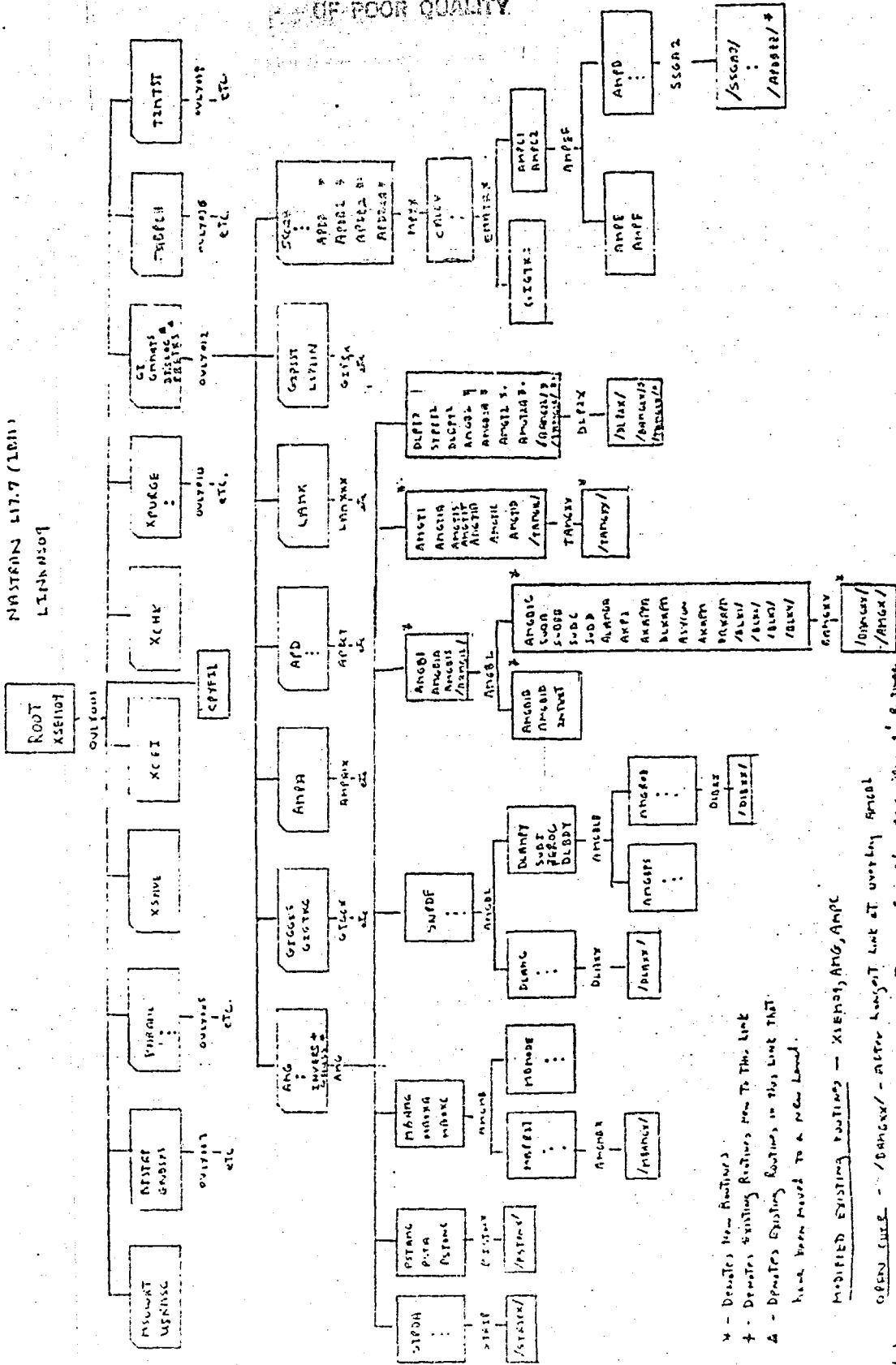
MODIFIED EXISTING ROUTINES: CYCLE, DUM#01, DUM#02

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3.24



NAVSTRON 117.7 (1011)
LITHANSON

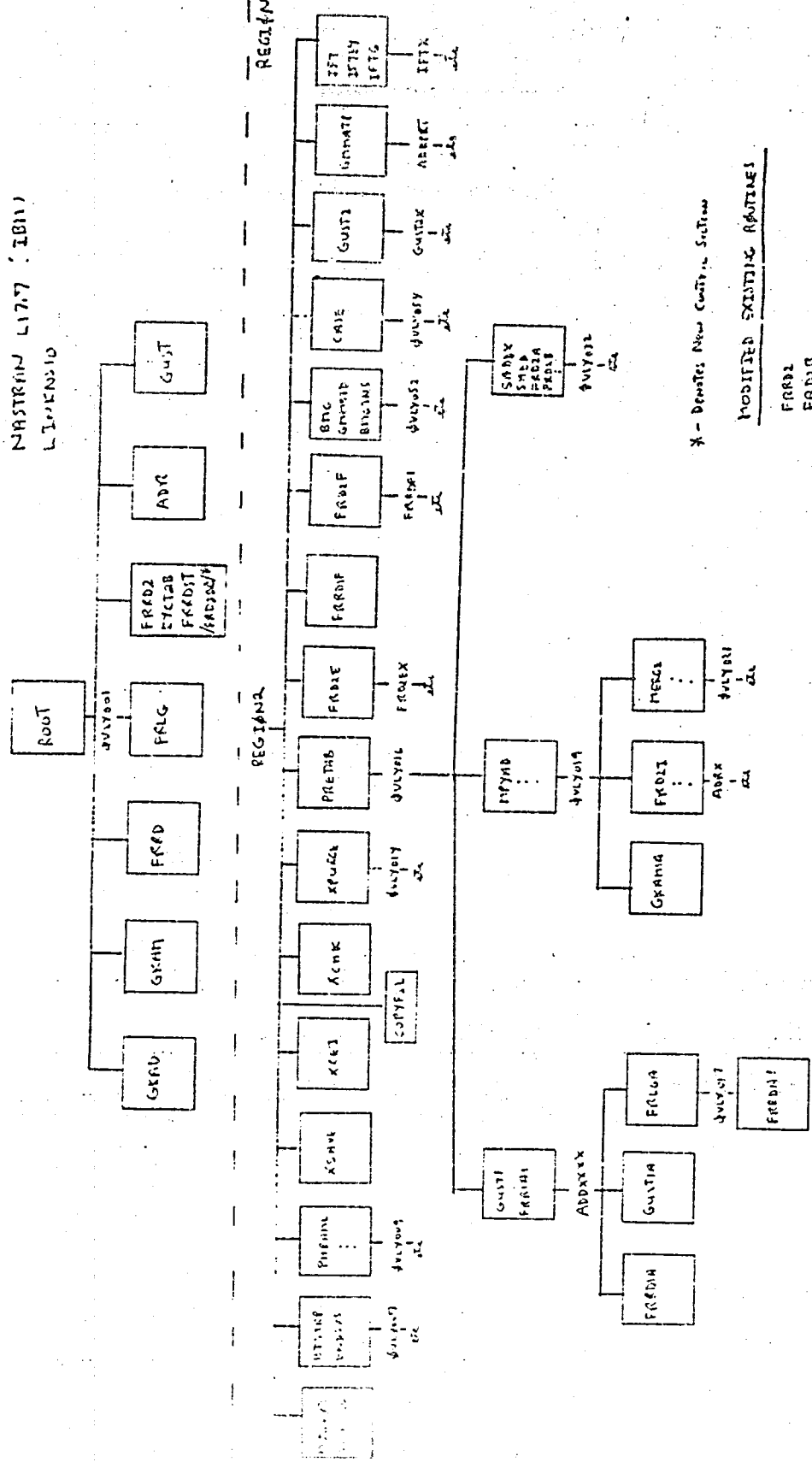


* - Denotes New Routines
 + - Denotes Existing Routines New To This Link
 Δ - Denotes Existing Routines in this Link that have been moved to a new Link.

MODIFIED EXISTING ROUTINES - XSEN01, ANG, ANGC, ANPC

OPEN LINK - /DANGX/ - After Longst Link at working ANPC
 XSEN01
 /ANGX/ - After Longst. Link of working ANG 'Prest' Routine
 /DUXX/ - After Longst Link of ANG 'Phase' Routine

NASTRIM L17.7 (IB11)
L17PENSIO



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* - Denotes New Country Section

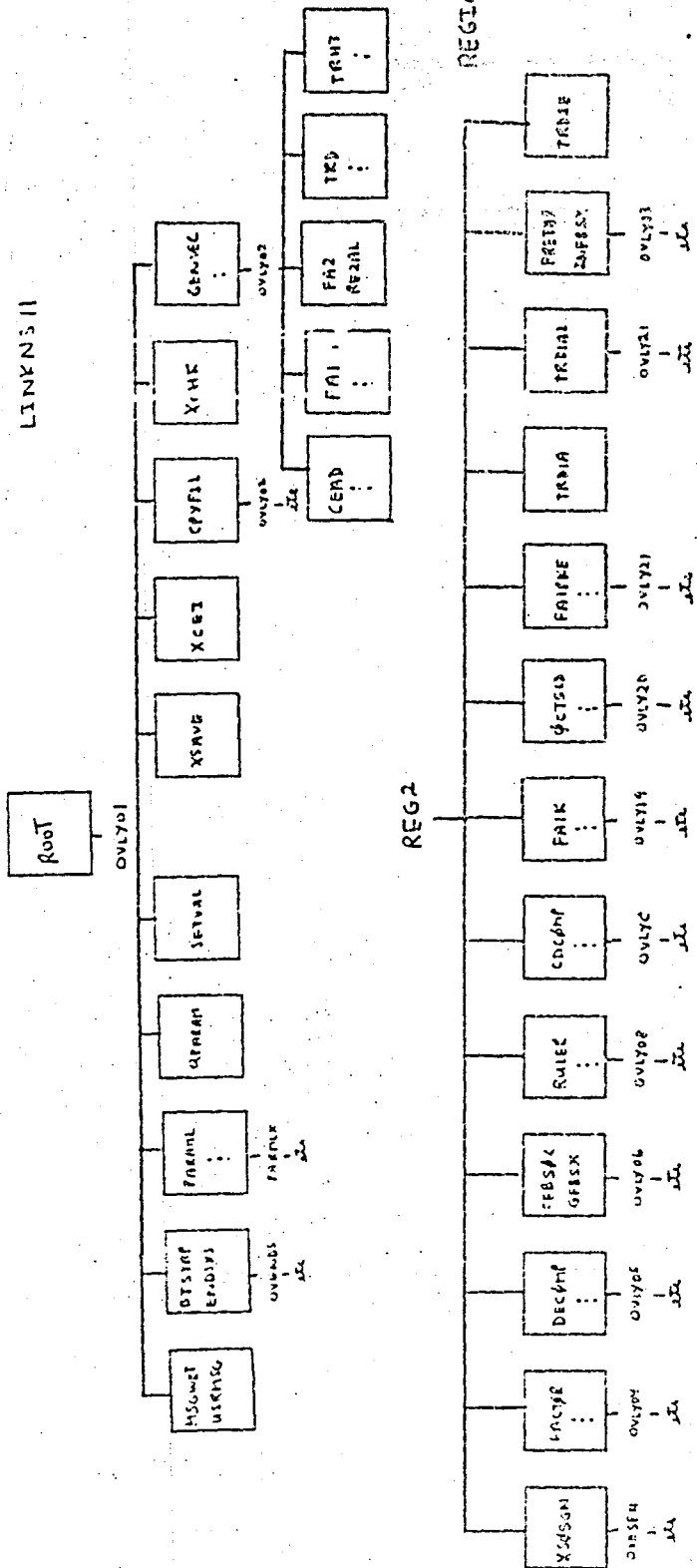
MODIFIED EXISTING ROUTINES!

- FRED2
- FREDI
- FREDAC



NA TRAIN L17.7 (IBH)

LINKS II



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MODIFIED EXISTING ROUTINES: FA2

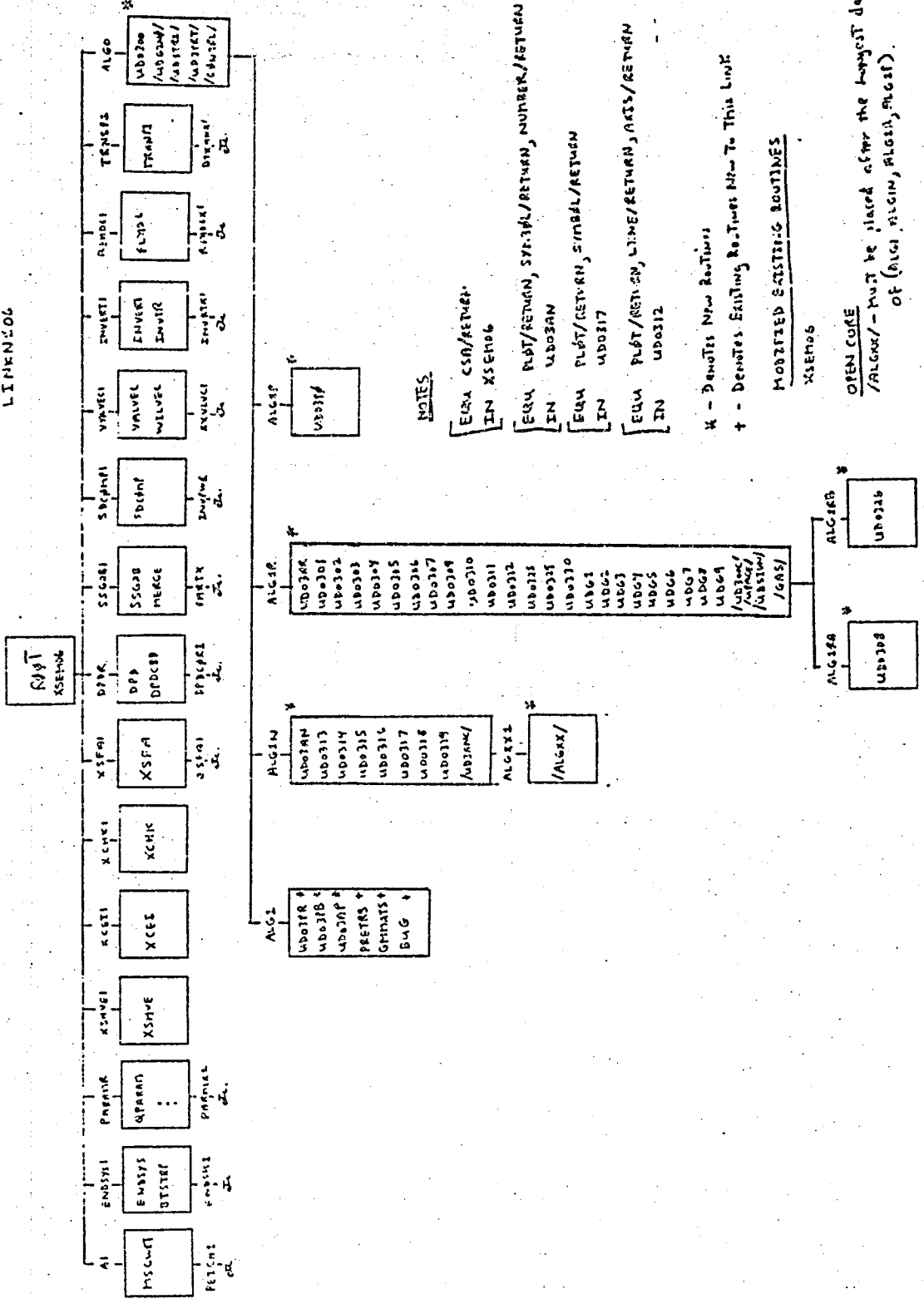


3.3.2 UNIVAC OVERLAY CHARTS

FOR NASTRAN LINKS

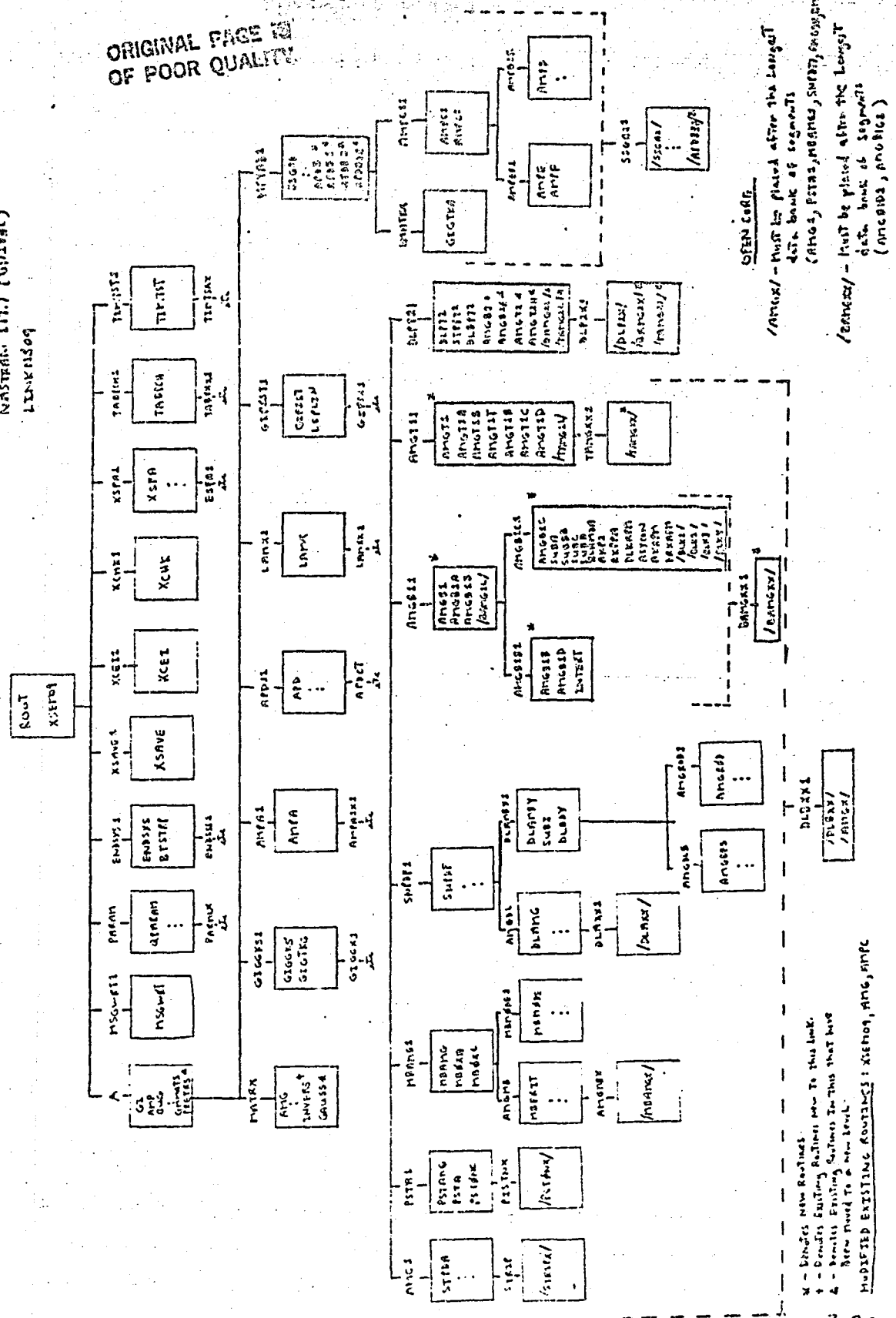
1, 6, 7, 9, 10, 11

NASTRAN L1.7 (JINJHC)
LINKN206



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MASTER LIST (CONT'D)
LAWSON



OPEN CURR

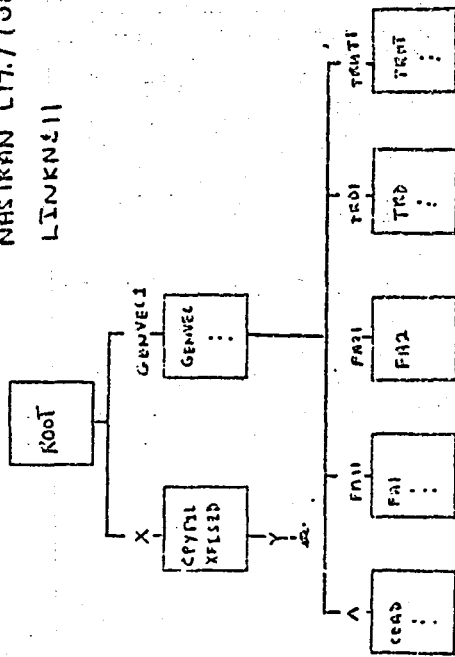
/ANXX/ - must be placed after the longest data bank of segments (AN03, PTA3, MBAN3, SUR3, SP03, SP04, SP05, SP06, SP07, SP08, SP09, SP10, SP11, SP12, SP13, SP14, SP15, SP16, SP17, SP18, SP19, SP20, SP21, SP22, SP23, SP24, SP25, SP26, SP27, SP28, SP29, SP30, SP31, SP32, SP33, SP34, SP35, SP36, SP37, SP38, SP39, SP40, SP41, SP42, SP43, SP44, SP45, SP46, SP47, SP48, SP49, SP50, SP51, SP52, SP53, SP54, SP55, SP56, SP57, SP58, SP59, SP60, SP61, SP62, SP63, SP64, SP65, SP66, SP67, SP68, SP69, SP70, SP71, SP72, SP73, SP74, SP75, SP76, SP77, SP78, SP79, SP80, SP81, SP82, SP83, SP84, SP85, SP86, SP87, SP88, SP89, SP90, SP91, SP92, SP93, SP94, SP95, SP96, SP97, SP98, SP99, SP100)

/BAXXX/ - must be placed after the longest data bank of segments (AN03, PTA3, MBAN3, SUR3, SP03, SP04, SP05, SP06, SP07, SP08, SP09, SP10, SP11, SP12, SP13, SP14, SP15, SP16, SP17, SP18, SP19, SP20, SP21, SP22, SP23, SP24, SP25, SP26, SP27, SP28, SP29, SP30, SP31, SP32, SP33, SP34, SP35, SP36, SP37, SP38, SP39, SP40, SP41, SP42, SP43, SP44, SP45, SP46, SP47, SP48, SP49, SP50, SP51, SP52, SP53, SP54, SP55, SP56, SP57, SP58, SP59, SP60, SP61, SP62, SP63, SP64, SP65, SP66, SP67, SP68, SP69, SP70, SP71, SP72, SP73, SP74, SP75, SP76, SP77, SP78, SP79, SP80, SP81, SP82, SP83, SP84, SP85, SP86, SP87, SP88, SP89, SP90, SP91, SP92, SP93, SP94, SP95, SP96, SP97, SP98, SP99, SP100)

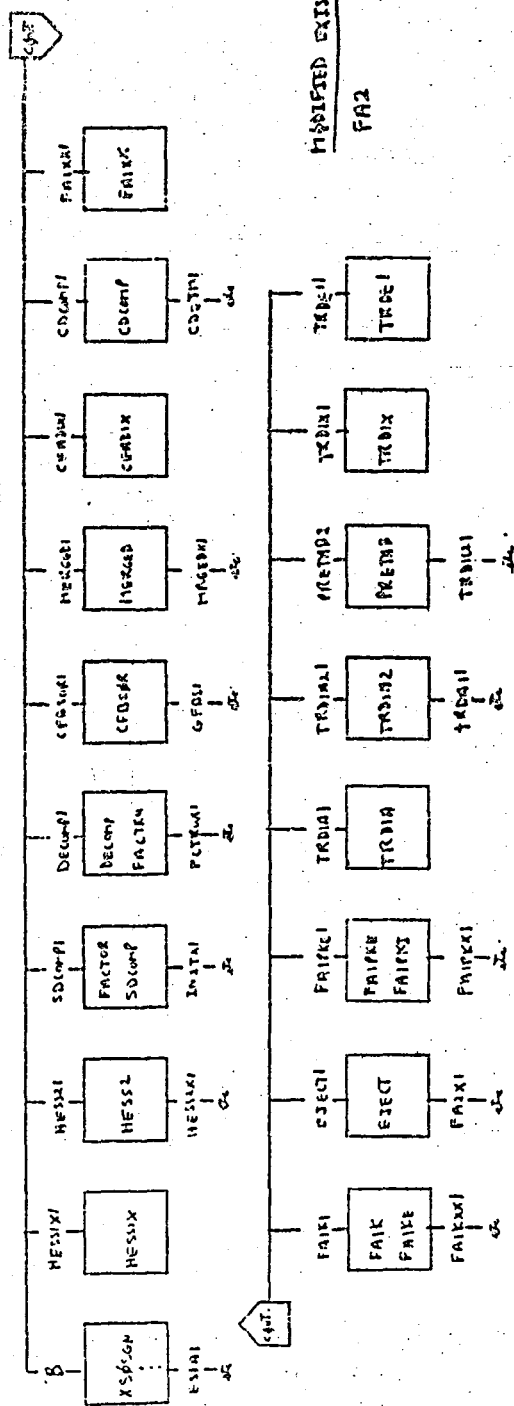
* - denotes New Routines
+ - denotes Existing Routines new to this level
- - - denotes Existing Routines in this that have been moved to a new level
MODIFIED EXISTING ROUTINES: XSERV, AN03, AN04

NASTRAN L17.7 (UNIJAC)
LINKN11

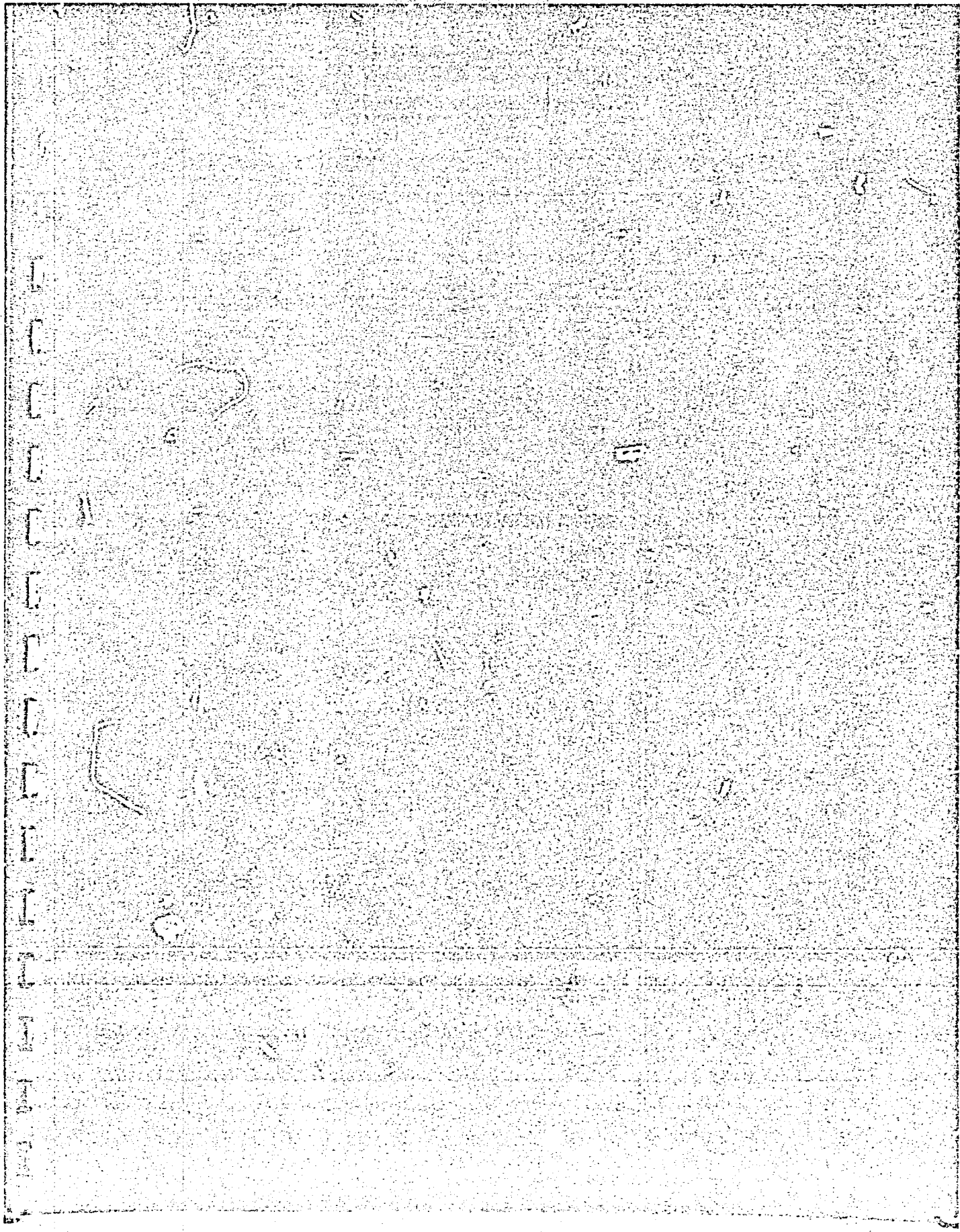
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PROG 1
SECTION 1



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 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-sec²/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. Description

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. Input

1. Parameters:

Same as general input parameters.

2. Constraints:

Same as general input constraints.

3. Loads:

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

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. Results

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	

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

ORIGINAL PAGE 74
 OF POOR QUALITY

KINDEX 2C TYPE LOADS

CASE CONTROL DECK ECHO

```

CARD
COUNT
1      $
2      TITLE = FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
3      SUBTITLE = BLADED DISC EXAMPLE 1 (FULL MODEL, FREQ LOADS)
4      LABEL = KINDEX 2C TYPE LOADS
5      $
6      SPC = 30
7      FREQ = 1
8      DLOAD = 1
9      OUTPUT
10     SET 1 = 8,22,36,50,64,78,92,106,120,134,148,162,
11           16,30,44,58,72,86,100,114,128,142,156,170,
12           18,32,46,60,74,88,102,116,130,144,158,172
13     OLOAD = 1
14     DISP(SORT2,PHASE) = ALL
15     STRESS(SORT2,PHASE) = ALL
16     OUTPUT(XYPLOT)
17     PLOTTER NASTPLT, MODEL D,0
18     XPAPER = 8.0
19     YPAPER = 10.5
20     XAXIS = YES
21     YAXIS = YES
22     XGRID LINES = YES
23     YGRID LINES = YES
24     CURVELINESYMBOL = 1
25     YLOG = YES
26     XTITLE = FREQUENCY (HERTZ)
27     YTITLE = GRID POINT DISPLACEMENTS ( MAGNITUDE, INCH )
28     TCURVE = 14(T3RM),18(T3RM),95(T3RM)
29     XYPLOT,XYPRINT DISP RESPONSE /14(T3RM),18(T3RM),95(T3RM)
30     YTITLE = ELEMENT STRESSES ( MAGNITUDE, PSI )
31     TCURVE = 11(3),11(5),11(7),11(10),11(12),11(14)
32     XYPLOT,XYPRINT STRESS RESPONSE /11(3),11(5),11(7),
33           11(10),11(12),11(14)
34     TCURVE = 109(3),109(5),109(7),109(10),109(12),109(14)
35     XYPLOT,XYPRINT STRESS RESPONSE /109(3),109(5),109(7),
36           109(10),109(12),109(14)
37     BEGIN BULK
  
```

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

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SORTED BULK DATA ECHO

	1	2	3	4	5	6	7	8	9	10
CORD2C	1			.0	.0	.0	1.0	.0	.0	GCOR_2
ECOR12	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	6				
CQUAD2	10	2	8	15	14	13				
CQUAD2	11	3	9	16	16	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					
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				

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SORTED BUNK 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	103				
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				
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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	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					

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S O R T E D B U C 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						

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SORTED BULK DATA ECHO

	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	1813.854	1832.0	1850.1	6FRI	
EFRI		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					

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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
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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SORTED BULK DATA ECHO

	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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SORTED BULK DATA ECHO

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	260.000	-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				

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SORTED BUCK DATA ECHO

	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				
MATI	1	30.066			.3	7.4-4				
PARAM	G	.02								
PQUAD2	2	1		.25						
PQUAD2	3	1		.125						
PTRIA2	1	1		.25						
RLOAD1	1	1								
SPC1	30	6	1		THRU	100				
SPC1	30	6	169		THRU	163				
SPC1	30	123456	1		10	24				
SPC1	30	123456	80		94	108	36	52	66	
TABLED1	100						122	136	150	
&TBD1	0.0	1.0	1000.0	1.0	ENDT					6T8D1
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:

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

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. 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

NASTRAN EXECUTIVE CONTROL DECK ECHO

ID NASA.EXAMPLE2
APP DISP
SOL 8

\$
\$
\$

\$ BEGINNING OF RF ALTER BSI - 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 CYCID 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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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

- 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. CYCLO - REQUIRED - THE INTEGER VALUE OF THIS PARAMETER SPECIFIES THE FORM OF THE INPUT AND OUTPUT DATA. A VALUE OF 01 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 TABLED BULK DATA CARDS WHICH DEFINE THE BXPTID COMPONENTS OF THE BASE ACCELERATION VECTOR. THE

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

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$$$  

ALTER 3 $  

FILE      UXVF=APPEND/PUT=APPEND/PO=APPEND $  

$ PERFORM INITIAL ERROR CHECKS ON NSEGS AND KMAX.  

CCND      ERRORC1,NSEGS $ IF USER HAS NOT SPECIFIED NSEGS.  

CCND      ERRORC1,KMAX $ IF USER HAS NOT SPECIFIED KMAX.  

PARAM     //C,N,EQ /V,N,CYCIOERR /V,Y,CYCIO=0 /C,N,0 $  

CCND      ERRORC1,CYCIOERR $ IF USER HAS NOT SPECIFIED CYCIO.  

PARAM     //C,N,DIY /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 $  

CCND      ERRORC1,KMAXERR $ IF KMAX .GT. NSEGS/2  

$ SET DEFAULTS FOR PARAMETERS.  

PARAM     //C,N,NUP /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,0.283185 $  

PARAMR    //C,N,MPY /V,N,OMEGAZ /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,NUT /V,N,NOLUMP /V,Y,COUPMASS=-1 $  

CCND      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  

$ MAKE 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,GLOM4,EQEXIN,GPDT,BGPDT,CTM/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,NUSET/S,N,NCL/S,N,NOA/C,Y,ASETOUT/S,Y,AUTOSPC $  

PURCE     GM,GMD/MPCF1/GU,GCD/CMIT/KFS,PSF,QPC/SINGLE $  

CHKPNT    GM,GMD,KG,GU,GDD,KFS,PSF,QPC,USET,YS $  

$ SUPORT BULK DATA IS NOT ALLOWED.  

PARAM     //C,N,NUT /V,N,REACDATA /V,N,REACT $  

CCND      ERRORC3,REACDATA $  

$ EXECUTE DPD NOW SO CHECKS CAN BE MADE. ADD TRL TO OUTPUT DATA BLOCKS.  

DPD       DYNAMICS,GPL,SIL,USET / GPLD,SILD,USED,TFPOOL,DLT,PSDL,FRL,  

          TRL,,EQDYN / V,N,LUSET/S,N,LUSETD/V,N,NOTFL/S,N,NOULT/  

          S,N,NOPSDL/S,N,NOFRL/V,N,NOCLFT/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 $  

CCND      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,TIMLSET $  

PARAM     //C,N,MPY /V,N,FREQTIME /V,N,FREQSET /V,N,TIMSET $

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ORIGINAL BASE 35
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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

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PARAM //C,N,NOT /V,N,FTERR1 /V,N,FREQTIME $
PAKAM //C,N,LE /V,N,NOFREQ /V,N,FREQSET /C,N,O $
PARAM //C,N,LE /V,N,NOTIME /V,N,TIMESET /C,N,O $
COND ERRURC6,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 ERRURC4,EXTRAPTS $
$ GENERATE DATA FOR CYCT2 MODULE.
CPCYC GEOM4,EDDYN,USETD /CYCDD /V,N,CTYPE=ROT /S,N,NOGU $
COND ERRURC1,NUGC $
CHKPNT CYCDD $
ALTER 32 $
$ PRF-PURGE DATA BLOCKS THAT WILL NOT BE GENERATED
PAKAM //C,N,OK /V,N,NOBMI /V,N,NOGG /V,N,NURPS $
PURGE BIGG,M1GG /NOBMI $
PURGE M2GG,M2BASEXG /NOGG $
ALTER 35 $
$ GENERATE DATA BLOCKS FRLX, BIGG, M1GG, M2GG AND BASEGX.
$ GENERATE PARAMETERS FKMAX AND NOBASEX.
DUMMOD1 CASECC,BOPDT,CSTM,DIT,FRL,MGG, / FRLX,B1GG,M1GG,
M2GG,BASEXG,PDZERC, /V,N,NOMGG/V,Y,LYCIC/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,NOBMI /C,N,O $ RESET NOBGG.
ALTER 52 $
$ REDEFINE BGG AND KGG.
COND LBL11A,NOBMI $
PARAMK //C,N,COMPLEX // V,N,OMEGA2 / C,N,O.O / V,N,CMLPX1 $
PARAMK //C,N,SUB / V,N,MOMEGASG / C,N,O.O / V,N,OMEGASOK $
PARAMK //C,N,COMPLEX // V,N,MOMEGASG / C,N,O.O / V,N,CMLPX2 $
ADD BGG,B1GG / BGG1 / C,N,(1.0,0.0) / V,N,CMLPX1 $
EQUIV BGG1,BGG $
ADD KGG,M1GG / KGG1 / C,N,(1.0,0.0) / V,N,CMLPX2 $
EQUIV KGG1,KGG $
CHKPNT BGG,KGG $
LABEL LBL11A
ALTER 53,55 $ GP4 HAS BEEN MOVED-UP.
ALTER 68,68 $ LPD 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/NCA/B2PP,B2DD/NAA/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, N3 AND N4 TO GKAD.
GKAD       USFTD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,
           GDD,K2DD,M2DD,B2DD/C,Y,GKAD=TRANRESP/C,N,DISP/C,N,DIRECT/
           C,Y,G=0.0/C,Y,N3=C.0/C,Y,N4=0.0/V,N,NOK2PP/V,N,NUM2FP/
           V,N,NOB2PP/V,N,MPCF1/V,N,SINGLE/V,N,UMIT/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 ALTLK 114 COMMENT.
JUMP       LGKAD4 $
LABEL      LGKAD3 $
EQUIV      B2DD,GDD/NOGPNT/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,REPEAT /C,N,1 /C,N,-1 $
PARAM      //C,N,ADD /V,N,APPFLG /C,N,1 /C,N,0 $ INITIALIZE FOR SDRI.
JUMP       TRLGLOOP $
LABEL      TRLGLOOP $
CASE       CASECC,/CASEYY/C,N,TRAN/S,N,REPEAT/S,N,NOLCOPI $
CHKPNT     CASEYY $
PARAM      //C,N,MPY /V,N,NCOL /C,N,0 /C,N,1 $
IRLG       CASEYY,USETD,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GDD,,EST,MGG/
           ,,PDT1,PD1,,TCL/ V,N,NOSET/S,N,PDEPDD/V,N,NCOL $
SDRI       TRL,PDT1,,,,,, / ,PDT, /V,N,APPFLG/C,N,DYNAMICS $
SDRI       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,REPEAT $
KEPT       TRLGLOOP,LOG $
JUMP       LRRGR3 $
LABEL      TRLGDONE $
CHKPNT     PDT,PD,IDL $
EQUIV      PD,PDT/PDEPDD $
CHKPNT     PDT $
DUMNUDZ    TDL,,,,,, / FRLZ,FOLZ,RECRDER1,RECRDER2,,,, /
           V,Y,NSEGS/V,Y,CYCIG/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,RECRDER1,RECRDER2 $
JUMP       LBLFRL2 $
LABEL      LBLTRL1 $
$ GENERATE FREQUENCY-DEPENDENT LOADS IF FREQUENCY WAS SELECTED IN CC.
```

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

```

FRLG        CASEXX,USSTD,DET,FRL,GND,GDD,DIT, / PPF,PSF,PDF,FUL,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 $
ADL         PPF,M2BASEXG / PPF1 /C,N,(1.0,0.0) /C,N,(-1.0,0.0) $
EQUIV       PPF1,PPF $
COND        LBLBASE1,NOSET $
SSG2        USSTD,GMD,YS,KFS,GDD,,PPF / ,PUDUML,PSF1,PDF1 $
EQUIV       PSF1,PSF // PDF1,PDF $
LABEL       LBLBASE1 $
LABEL       LBLFRL1 $
EQUIV       PPF,PDF/NOSET $
CHKPNT      PPF,PSF,PDF,FCL $
$ LOADS ARE FREQUENCY-DEPENDENT
$ PERFORM CYCLIC TRANSFORMATION ON LOADS IF CYCIC=&1.
PARAM       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/CYCIC $
COND        LBLPDONE,CYCIC $
$ CALCULATE THE NUMBER OF LOADS FOR CYCIC=1.
PARAM       //C,N,DIV /V,N,NLOAD /V,N,PDFCOLS /V,Y,NSEGS $ NLOAD = NF/NSEGS
CYCT1       PDF / PAF,GCYCF1 /V,N,CTYPE /C,N,FORE /V,Y,NSEGS=-1 /
            V,Y,KMAX=-1 / V,N,NLOAD /S,N,NOGG $
COND        ERRURCI,NOGG $
CHKPNT      PXF $
JUMP        LBLPDONE $
LABEL       LBLFRL2 $
$ LOADS ARE TIME-DEPENDENT
PARAM       //C,N,NOT /V,N,NOTCYCIC /V,Y,CYCIC $
$ BRANCH DEPENDING ON VALUE OF CYCIC
COND        LBLTRL2,NOTCYCIC $
$ CYCIC=-1
EQUIV       PDT,PDKZ1/NORD1 $
COND        LBLR01A,NOR01 $
MPYAD       PLT,REORDER1, / PTRZ1 / C,N,0 $
LABEL       LBLR01A $
CYCT1       PDKZ1 / PXTRZ1,GCYCF2 /V,N,CTYPE/C,N,FORE/V,N,NTSTEPS/
            V,Y,LMAX/V,N,FKMAX/S,N,NOGG $
COND        ERRURCI,NOGG $
CHKPNT      PXTRZ1 $
EQUIV       PXTRZ1,PXFZ1/NOR02 $
COND        LBLR02A,NOR02 $
MPYAD       PXTRZ1,REORDER2, / PXFZ1 /C,N,0 $
LABEL       LBLR02A $

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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

```
EQUIV    PXFZ1,PXF1 $
CHKPNT    PXF1 $
JUMP      LBLTRL3 $
LABEL     LBLTRL2 $
$ CYC10 = &1
MPYAD    PDT,REORDER1, / PDTRZ2 / C,N,0 $
CYC11    PDTRZ2 /PXTRZ2,GCYCF3 /V,N,CTYPE/C,N,FORE/V,N,NTSTEPS/V,Y,LMAX/
          V,Y,NSEGS/S,N,NOGC $
COND     EKRORC1,NOGC $
CHKPNT    PXTRZ2 $
EQUIV    PXTRZ2,PXTR2/NORD2 $
COND     LBLR02B,NORD2 $
MPYAD    PXTRZ2,REORDER2, / PXTR2 /C,N,0 $
LABEL     LBLR02B $
CYC11    PXTR2 / PXFZ2,GCYCF4 / V,N,CTYPE/C,N,FORE/V,Y,NSEGS/V,Y,KMAX/
          V,N,FLMAX/S,N,NOGC $
COND     EKRORC1,NOGC $
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 CYC12.
PARAM    //C,N,ADD /V,N,NLOAD /V,N,FLMAX /C,N,0 $ NLOAD = FLMAX.
LABEL    LBLPJONE $
PARAM    //C,N,ADD /V,N,KINDEX /V,Y,KMIN=0 /C,N,0 $ INITIALIZE 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 $
CYC12    CYCDD,,,PXF,, /,,PKFZ,, / C,N,FORE/V,Y,NSEGS/
          V,N,KMINV/V,N,CYCSEQ/V,N,NLOAD/S,N,NOGC $
COND     EKRORC1,NOGC $
ADD      PKFZ, / UKVFZ / C,N,(0,C,0,0) $
CYC12    CYCDD,,,UKVFZ,, /,,UXVF,, / C,N,BACK/V,Y,NSEGS/
          V,N,KMINV/V,N,CYCSEQ/V,N,NLOAD/S,N,NOGC $
COND     EKRORC1,NOGC $
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
```


NASTRAN EXECUTIVE CONTROL DECK ECHO

```

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 CONTRGL.
COND      ERRORC1,NOGC $
CHKPNT    BKKF,PKF $
$ SOLUTION
FRND2     KKKF,BKKF,MKKF,,PKF,FGL / UKVF /C,N,0.0/C,N,0.0/C,N,-1.0 $
CHKPNT    UKVF $
CYCT2     LYCDD,,,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      TOPCYL,100 $
JUMP      ERROR3 $
LABEL     LCYC2 $
EQUIV     JXVF,UDVF / CYC10 $
CHKPNT    UDVF $
COND      LCYC3,CYC10 $ - IF CYC10 .GE. 0 THEN TRANSFORM TO PHYSICAL.
CYLT1     UXVF / UDVF,GCYCB1 / V,N,CTYPE/C,N,BACK/V,Y,NSEGS/V,Y,KMAX/
           V,N,NLOAD $
CHKPNT    JDVF $
LABEL     LCYC3 $
COND      LBLTRL4,NOTIME $
EQUIV     PPF,PDF2 / CYC10 $
COND      LCYC4,CYC10 $ IF CYC10 .GE. 0 THEN TRANSFORM TO PHYSICAL.
CYLT1     PPF / 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,,,GMD,GMD,,, / PPFZ,, /C,N,1 /C,N,DYNAMICS $
SSC2      USETD,GMD,YS,KFS,GDD,,,PPFZ / ,PDUM,PSFZ,PLDUM $
EQUIV     PPFZ,PPF // PSFZ,PSF $
CHKPNT    PPF,PSF $
LABEL     LBLTRL4 $
ALTER 124,124 $ USE FGL INSTEAD OF PPF TO GET OUTPUT FREQUENCY LIST.
VDR       CASEXX,EQUYN,USETD,UDVF,FGL,XYCDB,/OUDVCL,/C,N,FREQRES/C,N,
           DIRECT/S,N,NGCORT2/S,N,NOD/S,N,NUP/C,N,0 $
ALTER 140,140 $ USE FGL 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,,,BGPOP,FLL,QPC,UPVC,EST,XYCDB,  
            PPF/UPPC1,QQPC1,DUPVCL,DESC1,GEFC1,PUPVCL/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.  
PKTPARM     //C,N,-7 /C,N,CYCSTATICS $  
LABEL        ERRORC2 $ COUPLED MASS NOT ALLOWED.  
PKTPARM     //C,N,0 /C,N,COUPMASS $  
JUMP         FINIS $  
LABEL        ERRORC3 $ SUPORT BULK DATA NOT ALLOWED.  
PKTPARM     //C,N,-6 /C,N,CYCSTATICS $  
LABEL        ERRORC4 $ EPCINT BULK DATA NOT ALLOWED.  
PKTPARM     //C,N,0 /C,N,NCUE $  
JUMP         FINIS $  
LABEL        ERRORC5 $ NEITHER FREQ OR TSTEP WERE IN BULK DATA DECK.  
PKTPARM     //C,N,0 /C,N,NDFRL $  
PKTPARM     //C,N,0 /C,N,NOTRL $  
JUMP         FINIS $  
LABEL        ERRORC6 $ BOTH FREQ AND TSTEP WERE SELECTED IN CASE CONTROL.  
PKTPARM     //C,N,0 /C,N,NDFREQ $  
PKTPARM     //C,N,0 /C,N,NOTIME $  
JUMP         FINIS $  
ENIALTER  
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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CASE CONTROL DECK ECHO

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.

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SORTED BULK DATA ECMO

	1	2	3	4	5	6	7	8	9	10
CORD2C	1									
ECOR12	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	ECOR12
CQUAD2	4	2	2	3	7	6				
CQUAD2	5	2	2	6	12	11				
CQUAD2	6	2	3	7	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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SORTED BULK DATA ECHO

	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	CFR1	
CFR1	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			
MAFI	1	30.086			.3		7.4-4			
PARAM	CYC10	81								
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				4.28	

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SORTED BULK DATA ECHO

1	2	3	4	5	6	7	8	9	10
TABLD1 100									ETSD1
GTBD1 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) $\bar{p}^{0,2c} = A(f)$ 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:

$$(1700 - 600) = \underline{1100} \text{ to } (1920 - 600) = \underline{1320} \text{ Hz, and}$$
$$(1700 + 600) = \underline{2300} \text{ to } (1920 + 600) = \underline{2520} \text{ Hz.}$$

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

NASTRAN EXECUTIVE CONTROL DECK ECHO

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

CASE CONTROL CASE 2008

CARD
COUNT

```
1 $
2 TITLE = FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
3 SUBTITLE = BLADED DISC EXAMPLE 3 (CYC MODEL) FREE BASE ACEN LOAD, HARM 1/01
4 $
5 SPC = 30
6 FREQ = 1
7 OUTPUT
8 SET 1 = 8,16,18
9 SET 2 = 11
10 GLOAD = 1
11 DISP(SORT2,PHASE) = 1
12 STRESS(SORT2,PHASE) = 2
13 SUBCASE 1
14 LABEL = KINDEX 0
15 DLOAD = 1 $ FREQ DEPENDENT LOADS
16 $ $ AXIAL BASE ACCN LOADS VIA PARAM BXTID,BXPTID
17 SUBCASE 2
18 LABEL = KINDEX 1C
19 $ $ LATERAL BASE ACCN LOADS VIA PARAM BYTID
20 SUBCASE 3
21 LABEL = KINDEX 1S
22 $ $ LATERAL BASE ACCN LOADS VIA PARAM BZTID
23 SUBCASE 4
24 LABEL = KINDEX 2C
25 DLOAD = 1 $ FREQ DEPENDENT LOADS
26 SUBCASE 5
27 LABEL = KINDEX 2S
28 OUTPUT(XYPLOT)
29 PLOTTER NASTPLT, MODEL D,0
30 XPAPER = 8.0
31 YPAPER = 10.5
32 XAXIS = YES
33 YAXIS = YES
34 XGRID LINES = YES
35 YGRID LINES = YES
36 CURVELINESYMBOL = 1
37 XTITLE = FREQUENCY (HERTZ)
38 YTITLE = GRID POINT DISPLACEMENTS ( MAGNITUDE, INCH )
39 YLOG = YES
40 TCURVE = 8(T3RH),18(T3RH)
41 XYPLOT,XYPRINT DISP RESPONSE 1 /8(T3RH),10(T3RH)
42 XYPLOT,XYPRINT DISP RESPONSE 2 /8(T3RH),10(T3RH)
43 XYPLOT,XYPRINT DISP RESPONSE 3 /8(T3RH),10(T3RH)
44 XYPLOT,XYPRINT DISP RESPONSE 4 /8(T3RH),10(T3RH)
45 YTITLE = GRID POINT DISPLACEMENTS ( PHASE,DEGREE )
46 TCURVE = NO
47 TCURVE = 8(T3IP),10(T3IP)
48 XYPLOT,XYPRINT DISP RESPONSE 2 /8(T3IP),10(T3IP)
49 YTITLE = ELEMENT STRESSES ( MAGNITUDE,PSI )
50 YLOG = YES
```


SORTED DATA

	1	2	3	4	5	6	7	8	9	10
COR2C	1		.0	.0	.0	1.0	.0	.0		80012
GOR12	0.0	1.0	0.0							
CQUAD2	4	2	2	3	7	6				
CQUAD2	5	2	6	7	12	11				
CQUAD2	6	2	3	6	8	7				
CQUAD2	7	2	7	8	13	12				
CQUAD2	8	2	4	5	9	0				
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	1822.85	1832.0	1850.1	8FR1	
8FR1	1860.0	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					
MATL	1	30.066		.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 D - U - O - G C - A - P - A G - C - M - O

1	2	3	4	5	6	7	8	9	10
PARAM	KHEN	0							
PARAM	LGRAD	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								GT001
GT001	0.0	1.0	1000.0	1.0	ENDT				
TABLED1	9001								GTAB11
GTAB11	1000.	0.0	2000.0	1000.0	ENDT				
TABLED1	9002								GTAB21
GTAB21	1000.	-180.	2000.0	0.0	ENDT				
TABLED1	9003								GTAB31
GTAB31	1000.	1000.0	2000.0	1000.0	ENDT				
TABLED1	9004								GTAB41
GTAB41	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 } Specify the form in which the damping parameters are
LGKAD = +1 } used.

2. Constraints:

Same as general input constraints.

3. Loads:

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

where n is the segment number,

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

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

$A(t) = A \cdot \sin(2\pi \cdot 1814 \cdot t)$.

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

NASTRAN EXECUTIVE CONTROL DECK ECHO

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

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CASE CONTROL DECK ECHO

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, XSCRT WILL RE-ORDER DECK.

4.40

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SORTED BULK DATA ECHO

1	2	3	4	5	6	7	8	9	10
CORD2C	1		.0		.0		.0		ECOR12
ECOR12	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	0	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					

SCRTED BULK DATA ECHO.

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		5.7	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				
MA71	1	30.086		.3	7.4-4				
PARAM	CYCLO	61							
PARAM	G	.02							
PARAM	GKAD	FRECRSP							
PARAM	KMAX	2							
PARAM	KMIN	2							
PARAM	LGKAD	1							
PARAM	LVAX	1							
PARAM	NSEGS	12							
PARAM	RPS	600.0							
POLAD2	2	1	.25						
POLAD2	3	1	.125						
POLAD2	1	1	.25						
SPC1	30	6	1	THRU	19				
SPC1	30	123456	1	17					
TLAD2	1	1			.0	5.5131-41813.854-90.0			
TLAD2	2	2			.0	5.5131-41813.854-90.0			
TLAD2	3	3			.0	5.5131-41813.854-90.0			
TLAD2	4	4			.0	5.5131-41813.854-90.0			
TLAD2	5	5			.0	5.5131-41813.854-90.0			
TLAD2	6	6			.0	5.5131-41813.854-90.0			
TLAD2	7	7			.0	5.5131-41813.854-90.0			
TLAD2	8	8			.0	5.5131-41813.854-90.0			
TLAD2	9	9			.0	5.5131-41813.854-90.0			
TLAD2	10	10			.0	5.5131-41813.854-90.0			
TLAD2	11	11			.0	5.5131-41813.854-90.0			
TLAD2	12	12			.0	5.5131-41813.854-90.0			
TSTEP	1	10	4.5943-51						

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SORTED BULK DATA ECHO.

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

L GKAD = +1 } are used.

2. Constraints:

Same as general input constraints.

3. Loads:

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

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

NASTRAN EXECUTIVE CONTROL DECK ECHO

```
ID      NASA,EXAMPLE5
APP     DISP
SOL     8
$
$      ALTER PACKAGE AS IN EXAMPLE2
$
TIME    3 $ IBM 370/3031
DIAG    8,14,21
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 5 (CYC MODEL, TIME DEP. LOAD, HARM 1/0)  
4      $  
5      SPC = 30  
6      TSTEP = 1  
7      OUTPUT  
8      SET 1 = 8,16,18  
9      SET 2 = 11  
10     DLOAD = 1  
11     DISP(SCRT2,REAL) = 1  
12     STRESS(SCRT2,REAL) = 2  
13     SUBCASE 1  
14         LABEL = KINDEX 0  
15         DLOAD = 99 $ NULL LOAD  
16     SUBCASE 2  
17         LABEL = KINDEX 10  
18         DLOAD = 99 $ NULL LOAD  
19     SUBCASE 3  
20         LABEL = KINDEX 15  
21         DLOAD = 99 $ NULL LOAD  
22     SUBCASE 4  
23         LABEL = KINDEX 20  
24         DLOAD = 1 $ TIME DEPENDENT LOADS  
25     SUBCASE 5  
26         LABEL = KINDEX 25  
27         DLOAD = 99 $ NULL LOAD  
28     BEGIN BULK
```

OPERATION MESSAGE 207, BULK DATA NOT SCRTED, XSCRT WILL RE-ORDER DECK.

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SCRTED BULK DATA ECHD

	1	2	3	4	5	6	7	8	9	10
CCPDZC	1		.0		.0		1.0	.0	.0	CCOR12
CCOR12	0.0	1.0	0.0							
COLAD2	4	2	2	3	7		6			
COLAD2	5	2	6	7	12		11			
COLAD2	6	2	3	4	8		7			
COLAD2	7	2	7	8	13		12			
COLAD2	8	2	4	5	9		8			
COLAD2	10	2	8	15	14		13			
COLAD2	11	3	9	16	18		15			
COLAD2	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					
CYJGIN	1		1	2	3	4	5			
CYJGIN	2		10	11	12	13	14			
DARFA	1	8	3	-1.0						
DARFA	1	16	3	1.0						
DARFA	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					
MATI	1	30.0E6		.3	7.4-4					
PARAM	CYCIC	-1								
PARAM	G	.02								
PARAM	GKAD	FRECFESP								
PARAM	KMAX	2								
PARAM	KMTA	2								
PARAM	LGKAD	1								
PARAM	LMAX	1								
PARAM	NSEGS	12								
PARAM	FPS	600.0								
POLAD2	2	1	.25							

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SCRTED BULK DATA ECHO

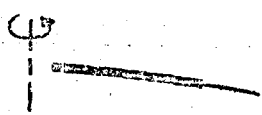


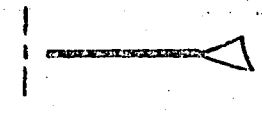
	1	2	3	4	5	6	7	8	9	10
POLAD2	3	1	.125							
PTRIA2	1	1	.25							
SPC1	30	6	1	THRU	19					
SPC1	30	123456	1	10						
TASLED1	9999								6TTT	
ETTT	0.0	0.0	1.0	0.0	ENDT					
TLOAD1	99	1	0		9999					
TLOAD2	1	1			.0				5.5131-41813.854-90.0	
TSTEP	1	10	4.5943-51							
ENDDATA										

TABLE 1: PRINCIPAL FEATURES DEMONSTRATED BY EXAMPLE PROBLEMS

Example No.	Finite Element Model of	Applied loads specified as functions of				Base Acceleration	Rotational Speed
		Frequency (sinusoidal)		Time (periodic)			
		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

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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	Example 3
	Segment 1 (subcase 1) Mag. (in)/Phase (deg)	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	Example 4	Example 5
	k = 2c (subcase 4) Mag.(in)/Phase(deg)	Segment 1 (subcase 1) Mag.(in)/Phase(deg)	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.

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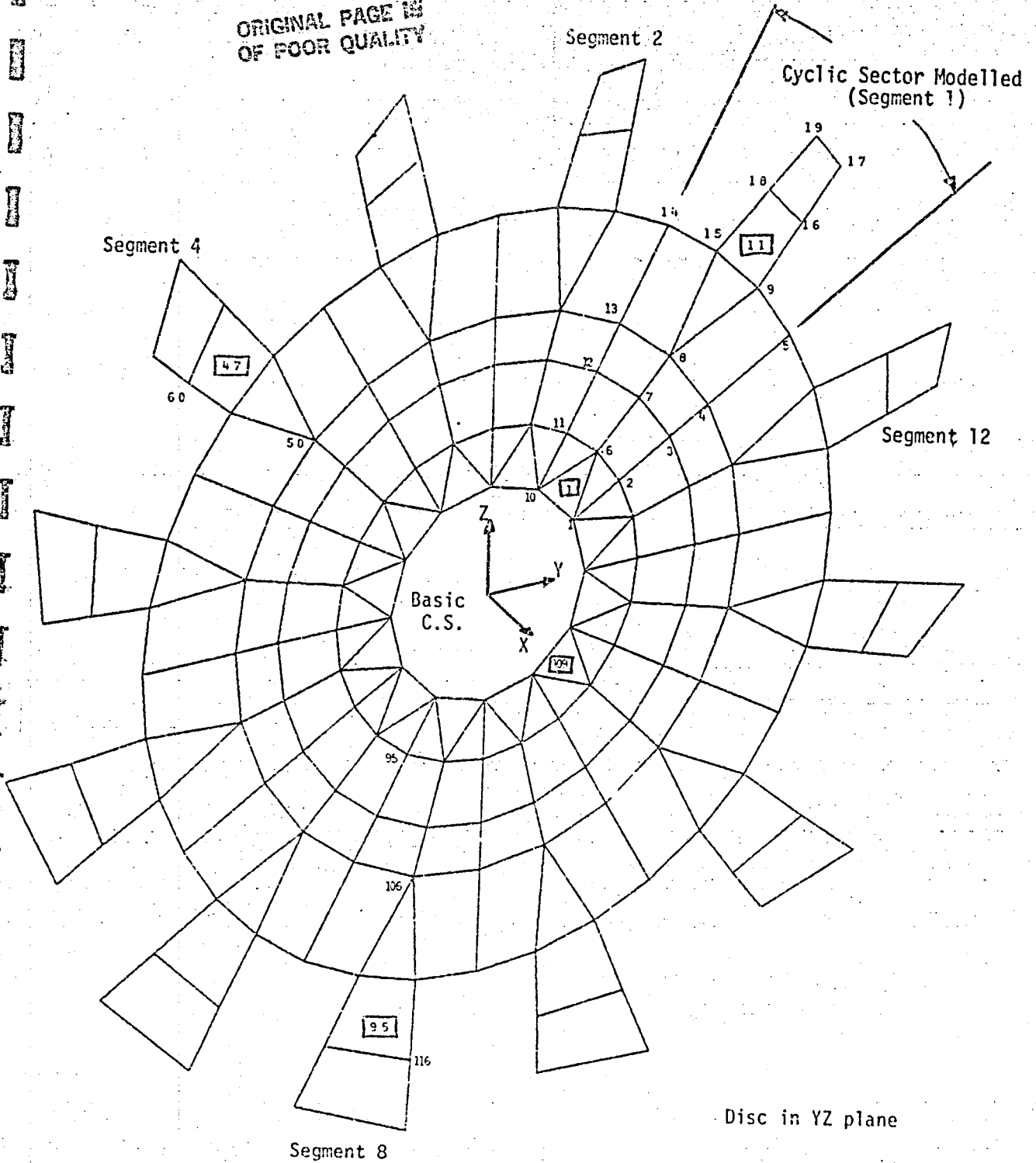
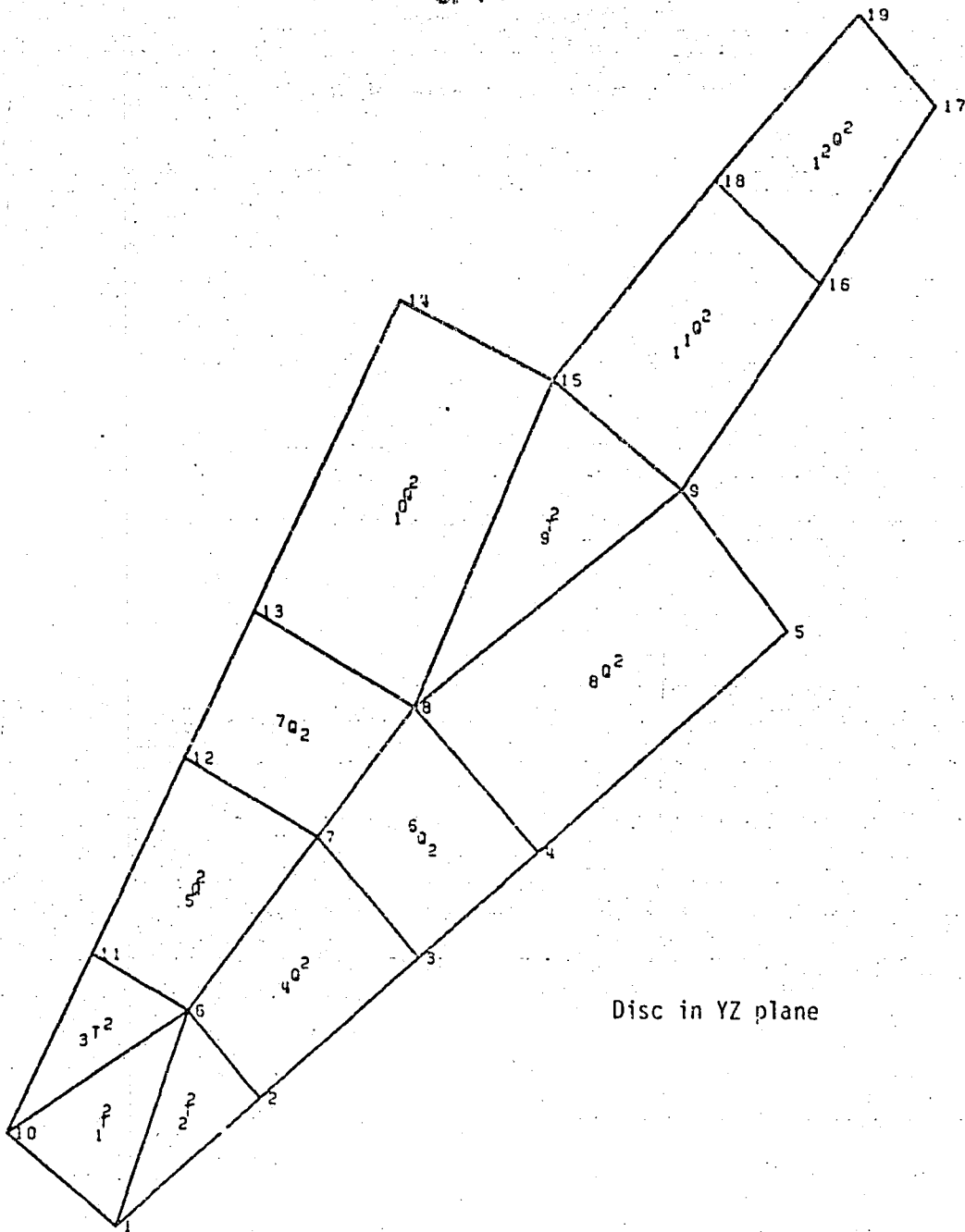


Figure 1: NASTRAN Model of the 12-Bladed Disc

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Disc in YZ plane

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

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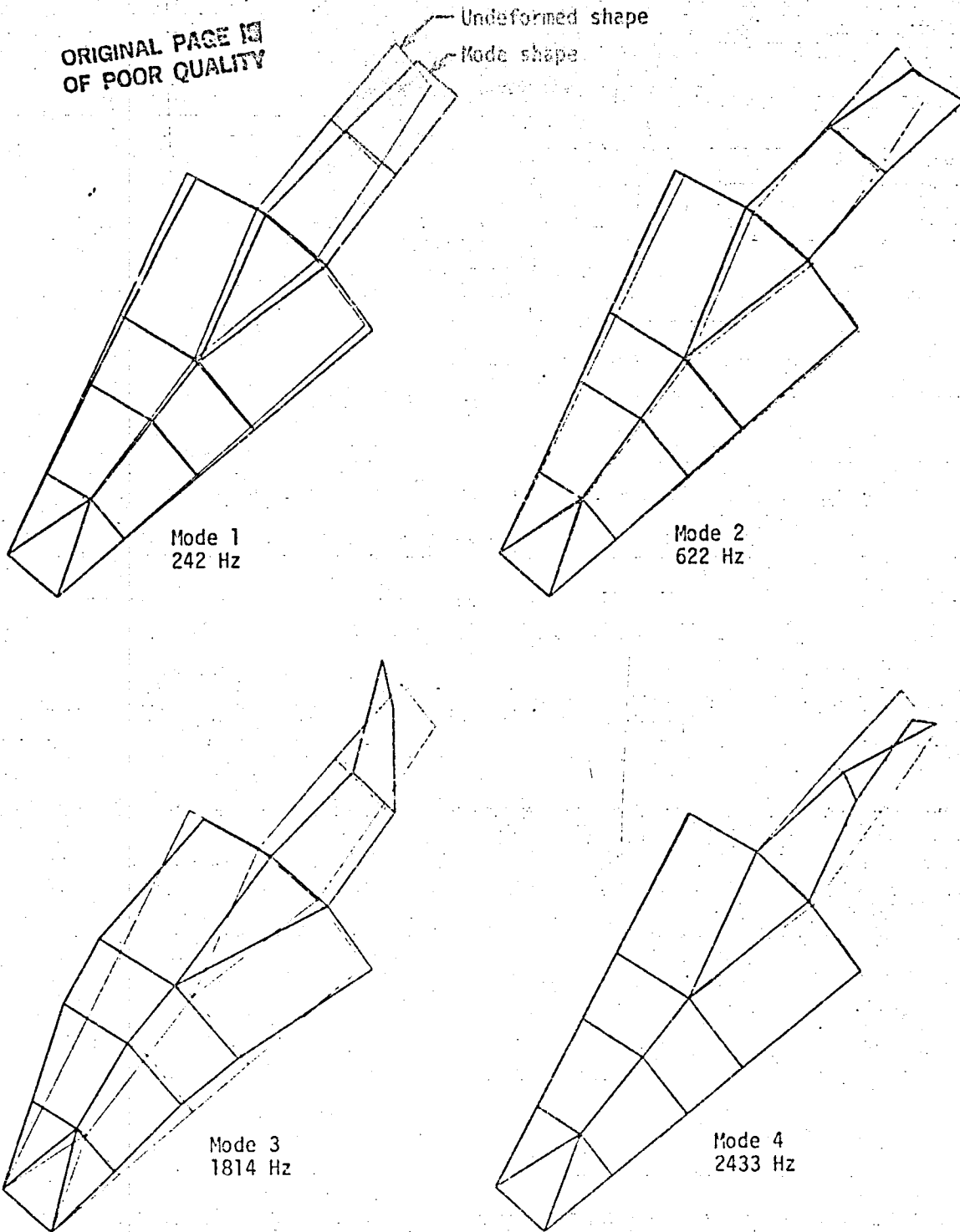
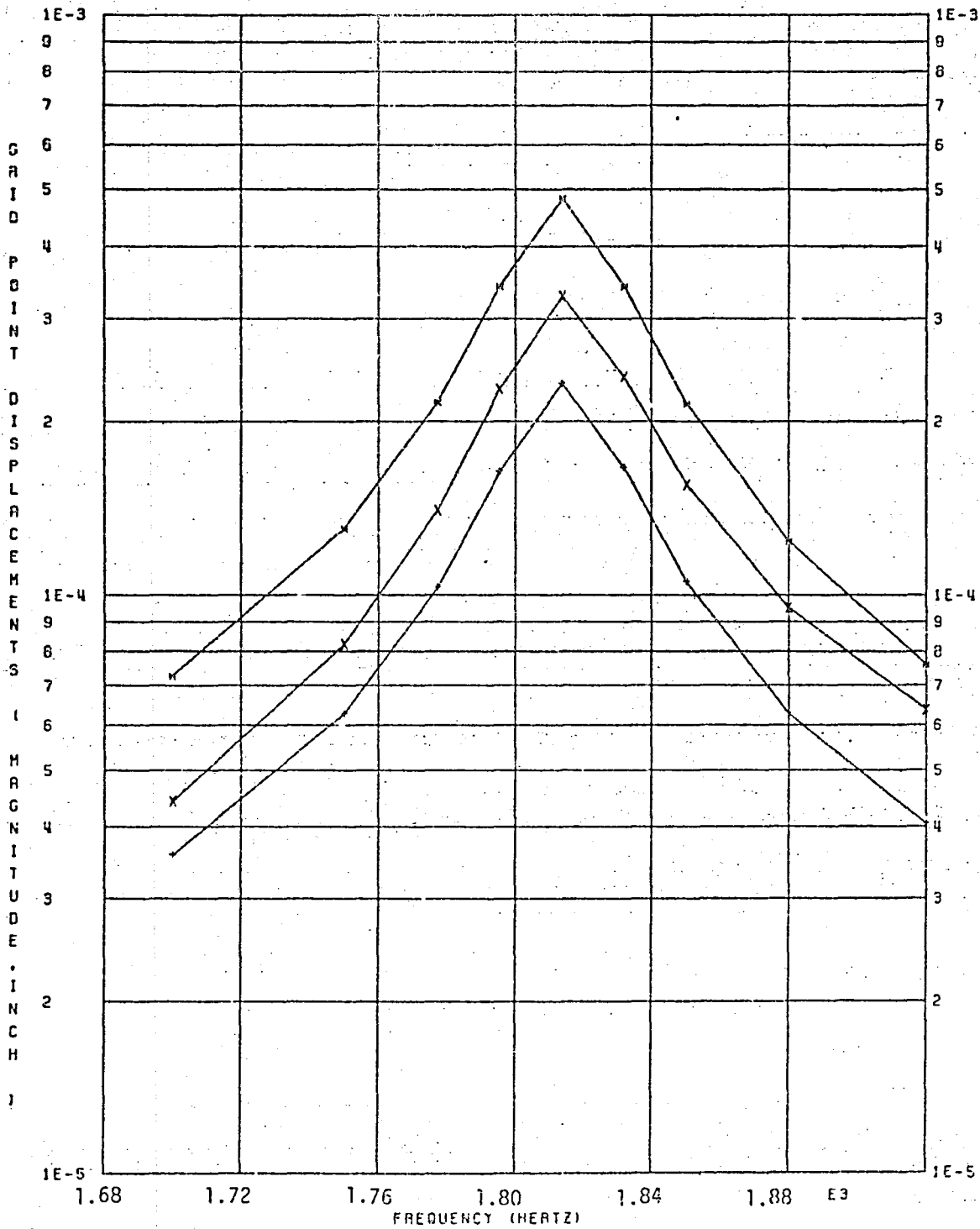


Figure 3: $k \neq 2$ Modes of Bladed Disc



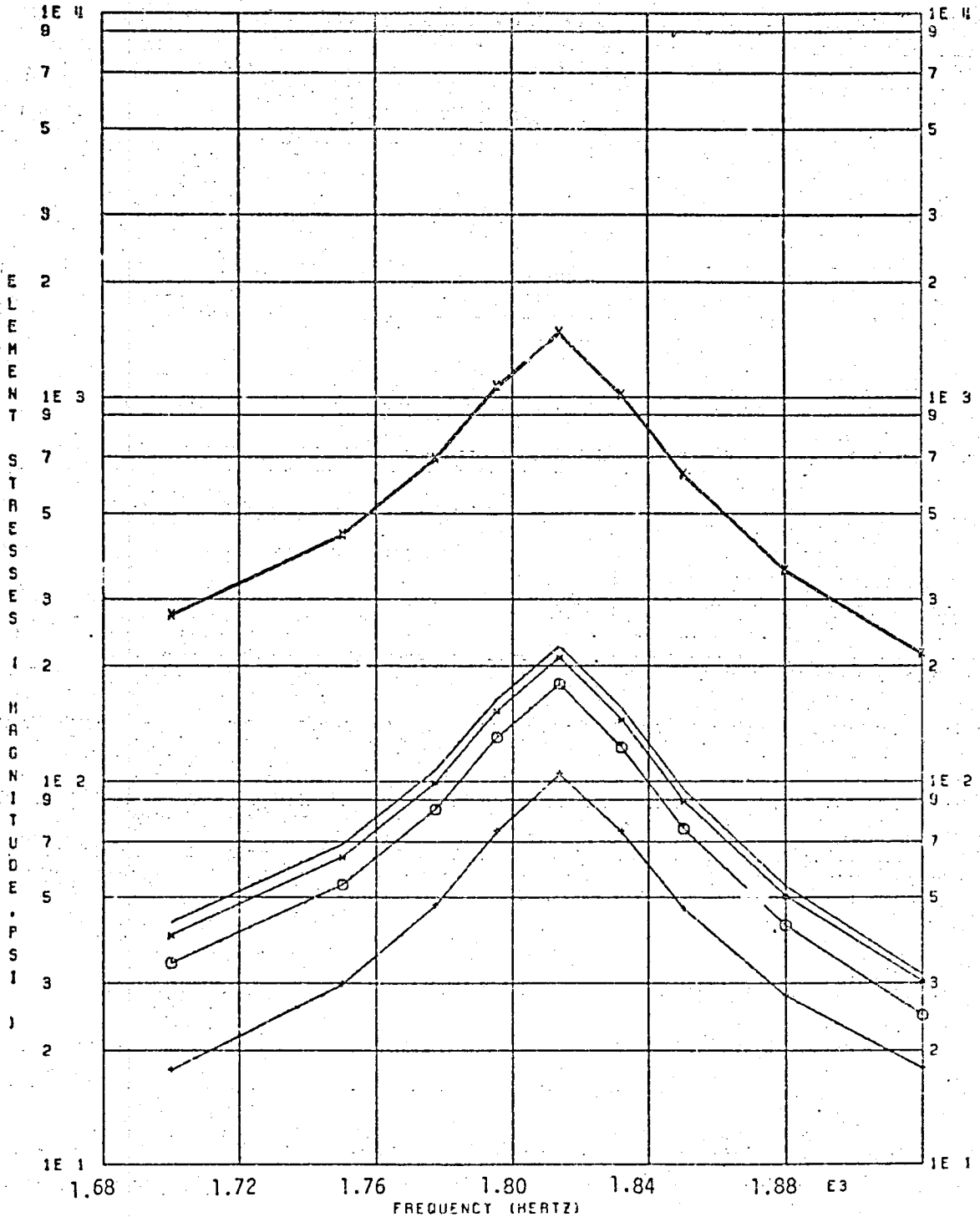
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14(T3RM), 18(T3RM), 95(T3RM)
 FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES.
 BLADED DISC EXAMPLE 1 (FULL MODEL, FREQ LOADS)
 KINDEX 2C TYPE LOADS

Figure 4

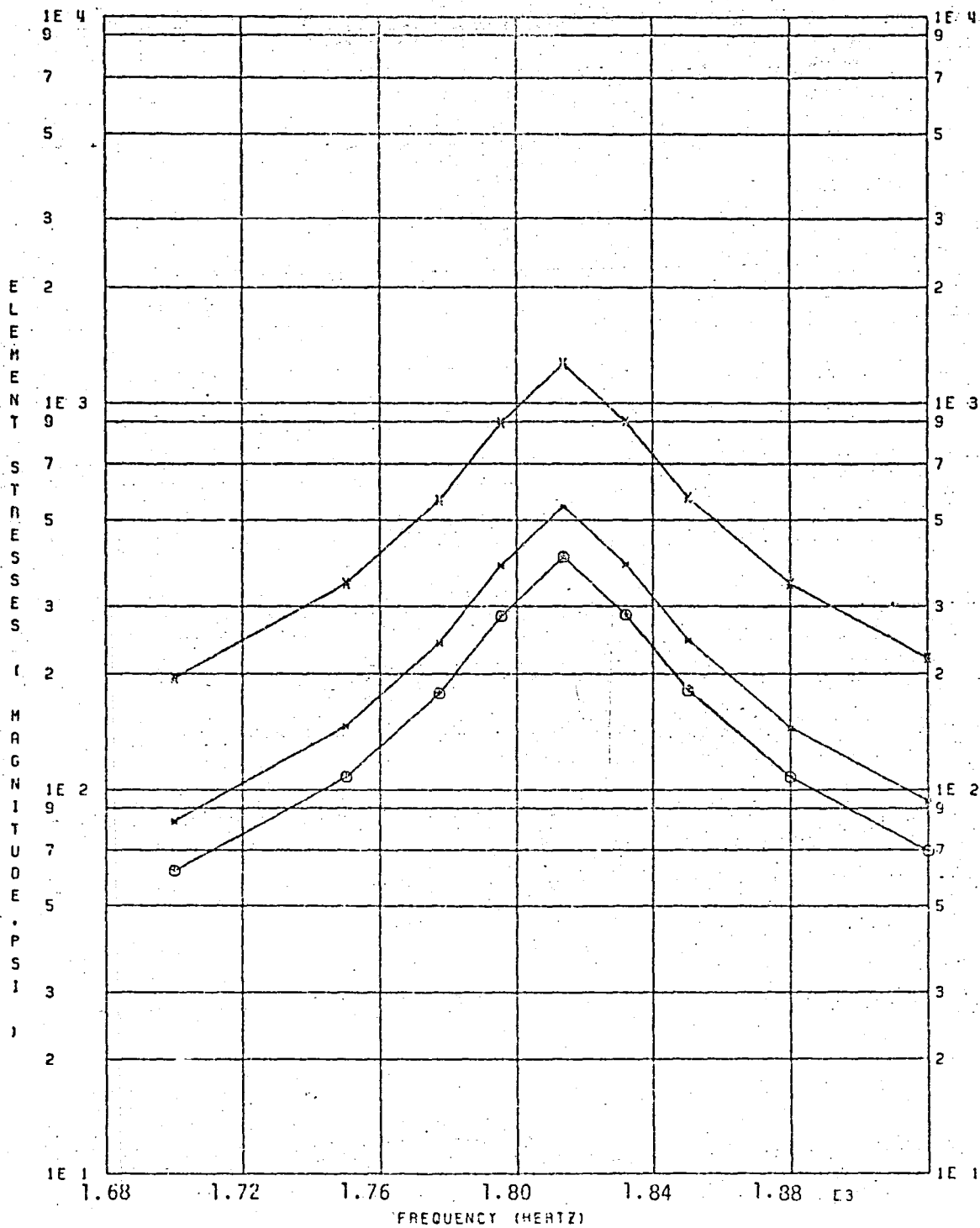
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11 (3), 11 (5), 11 (7), 11 (10), 11 (12), 11 (14)
 FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
 BLADED DISC EXAMPLE 1 (FULL MODEL, FREQ LOADS)
 KINDEX 20 TYPE LOADS

Figure 5

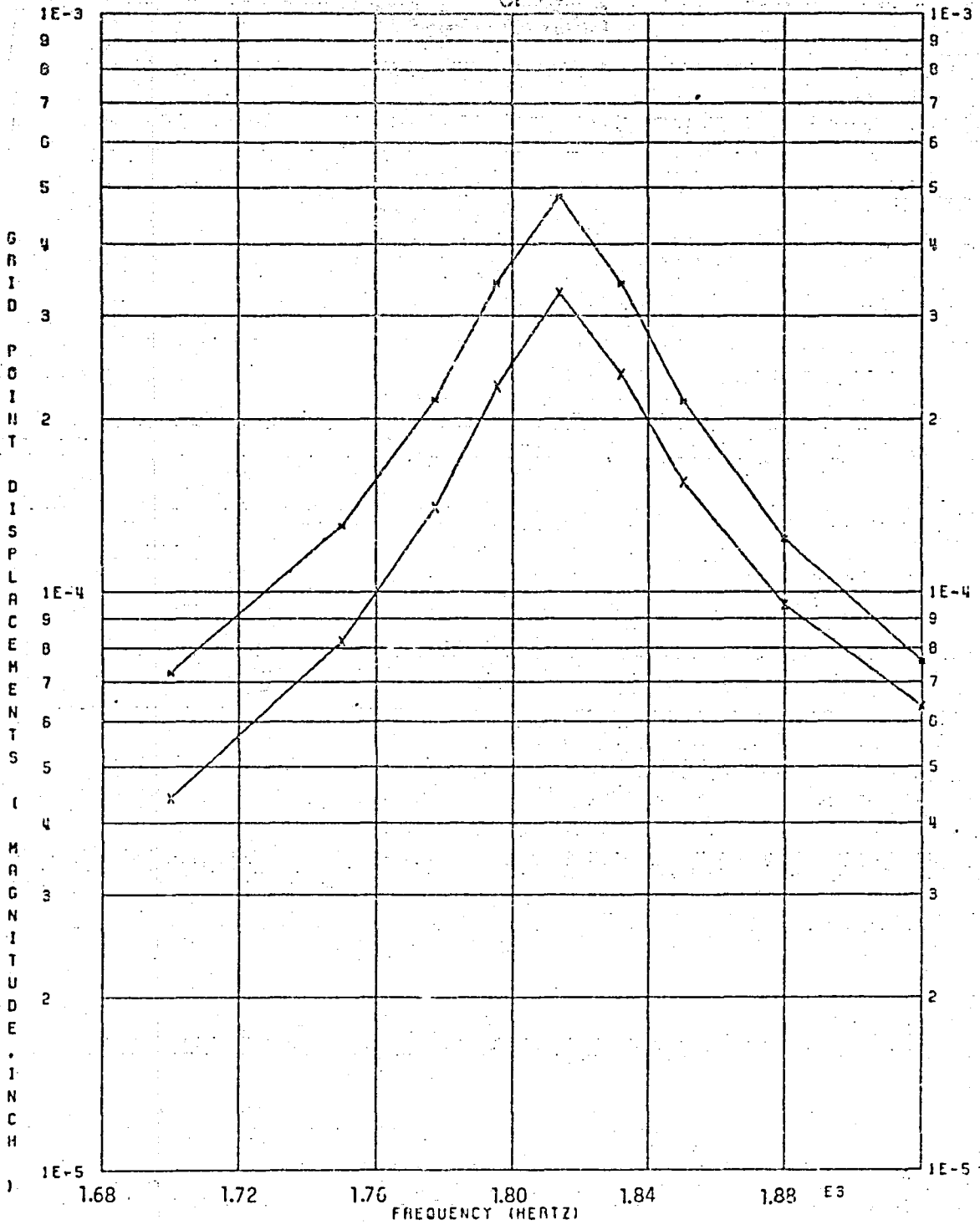
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109(3), 109(5), 109(7), 109(10), 109(12), 109(14)
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 BLADED DISC EXAMPLE 1 (FULL MODEL, FREQ LOADS)
 KINEX 2C TYPE LOADS

Figure 6

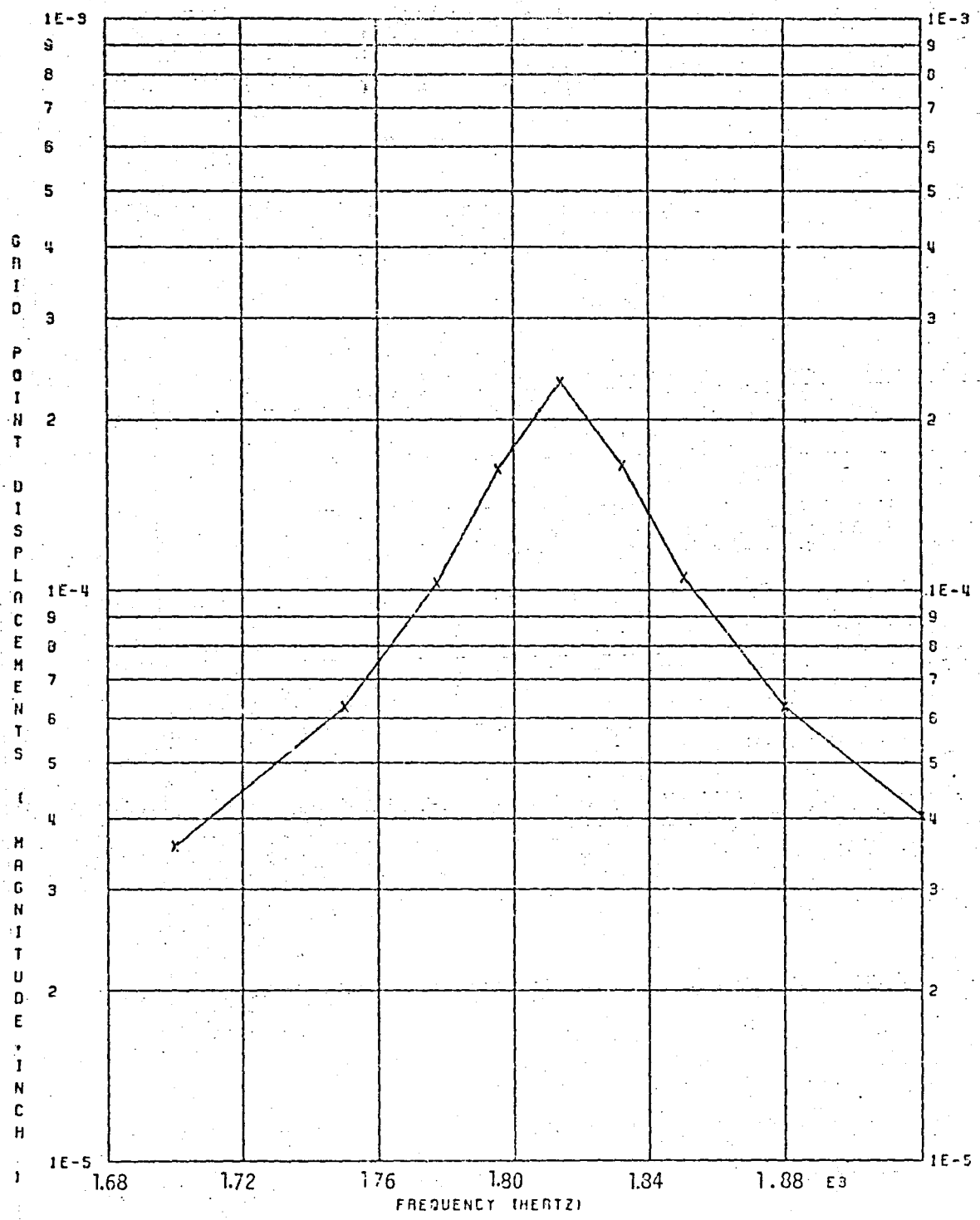
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14 (T3RM), 18 (T3RM)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 2 (CYC MODEL, FREQ LOADS, PHYSICAL I/O)
SEGMENT 1
SUBCASE 1

Figure 7

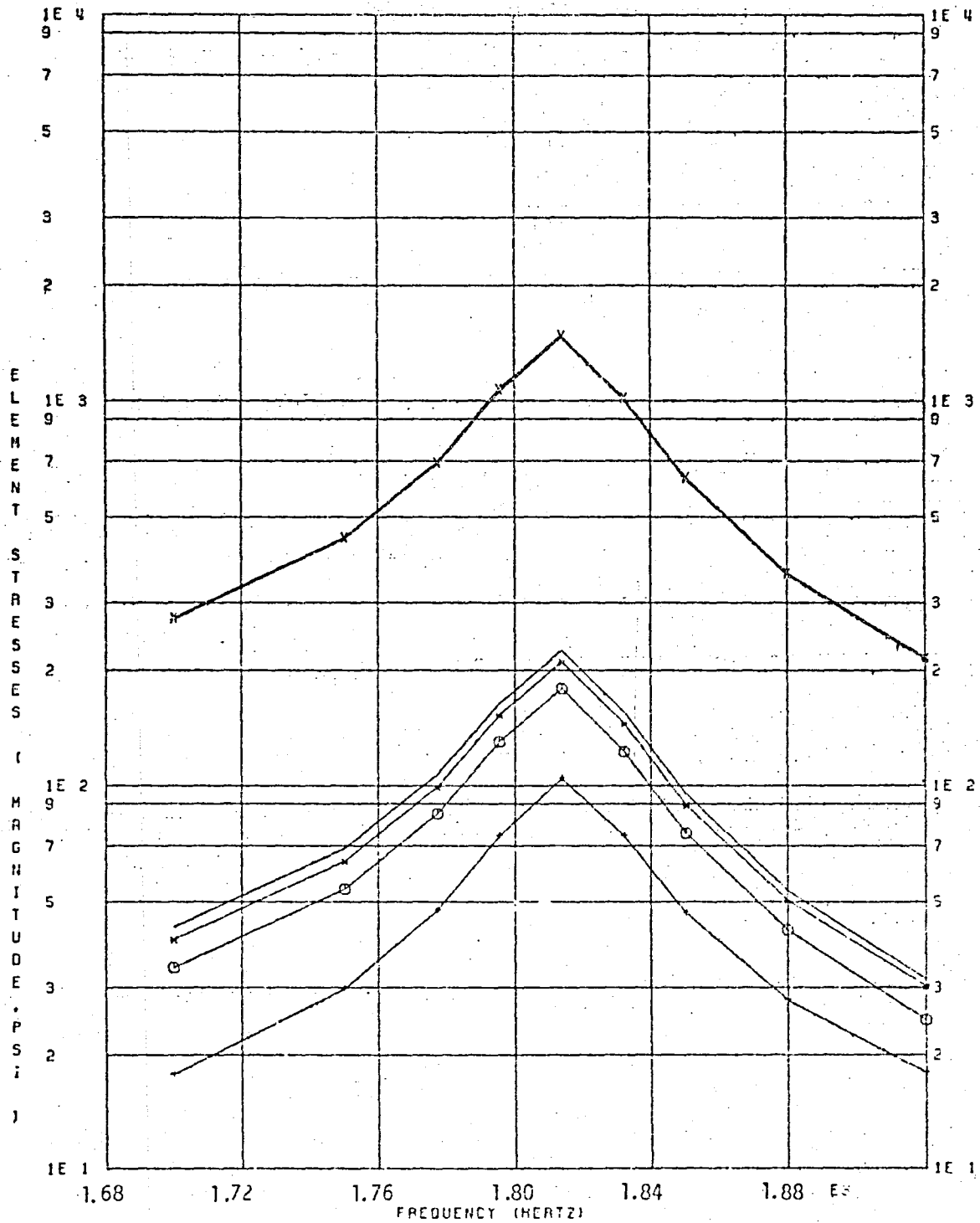
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2 (T3RM)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 2 (CYC MODEL, FREQ LOADS, PHYSICAL 1/0)
SEGMENT 8
SUBCASE 8

Figure 8

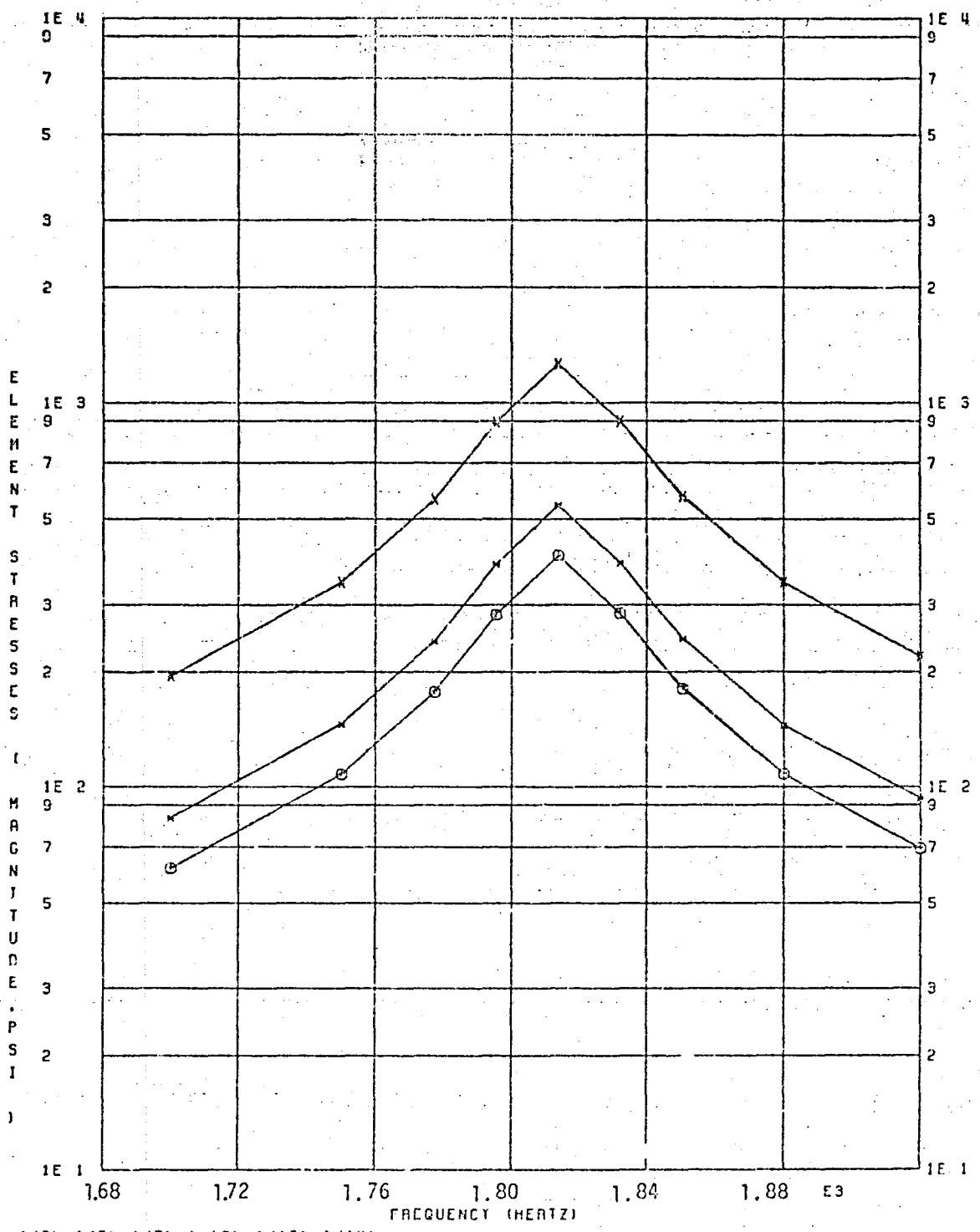
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11 (3), 11 (5), 11 (7), 11 (10), 11 (12), 11 (14)
 FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
 BLADED DISC EXAMPLE 2 (CYC MODEL, FREQ LOADS, PHYSICAL 1/3)
 SEGMENT 1 SUBCASE 1

Figure 9

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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 1/0)
 SEGMENT 10 SUBCASE 10

Figure 10

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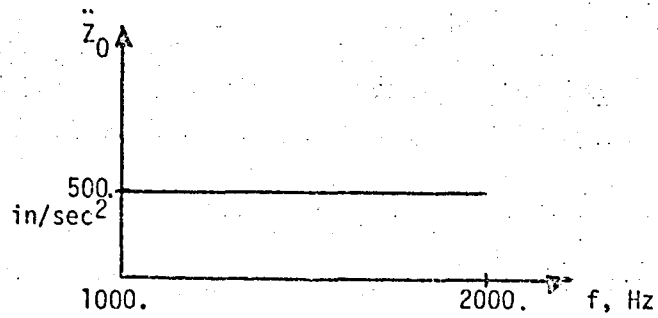
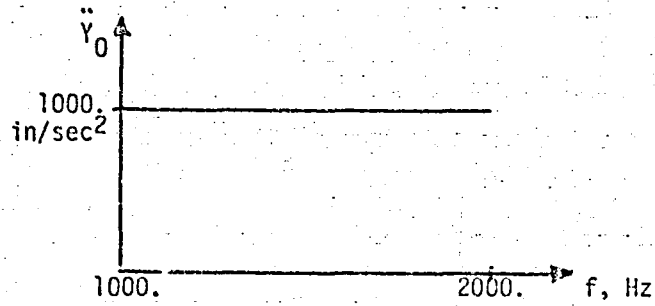
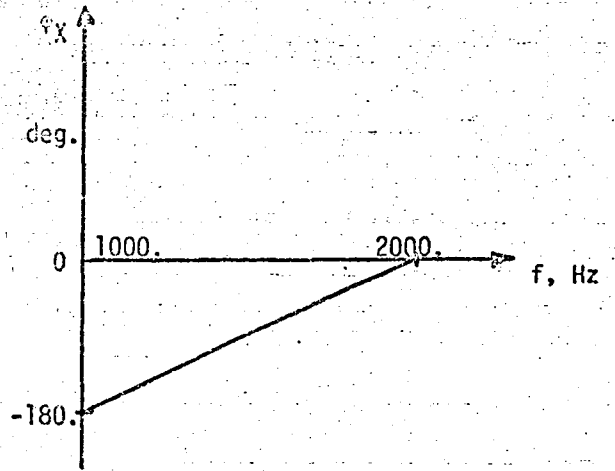
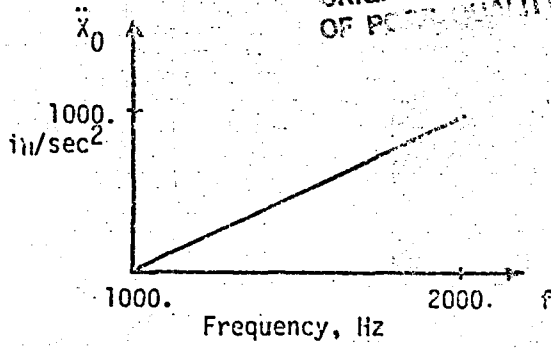
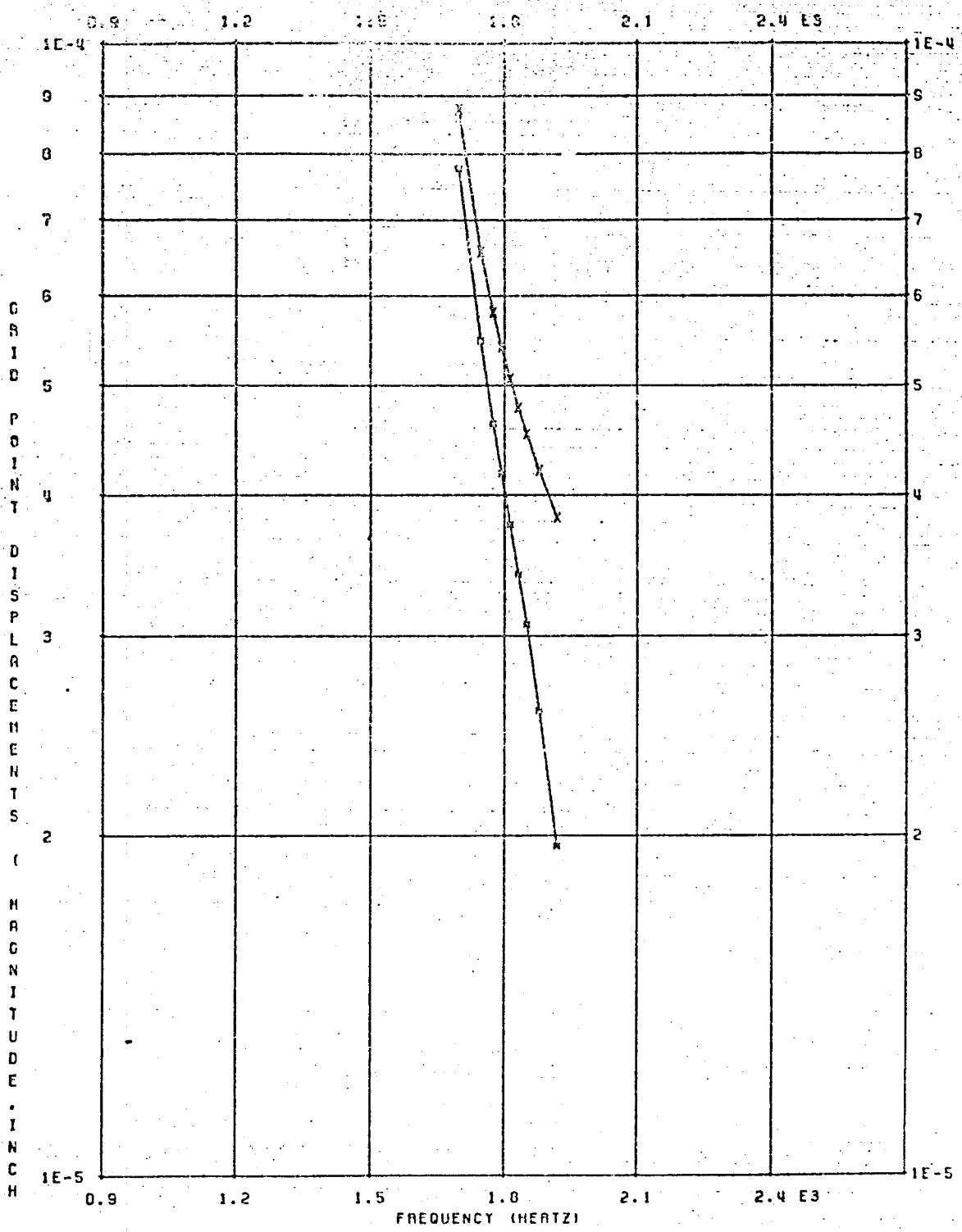


Figure 11: Base Acceleration Data in an Inertial Coordinate System

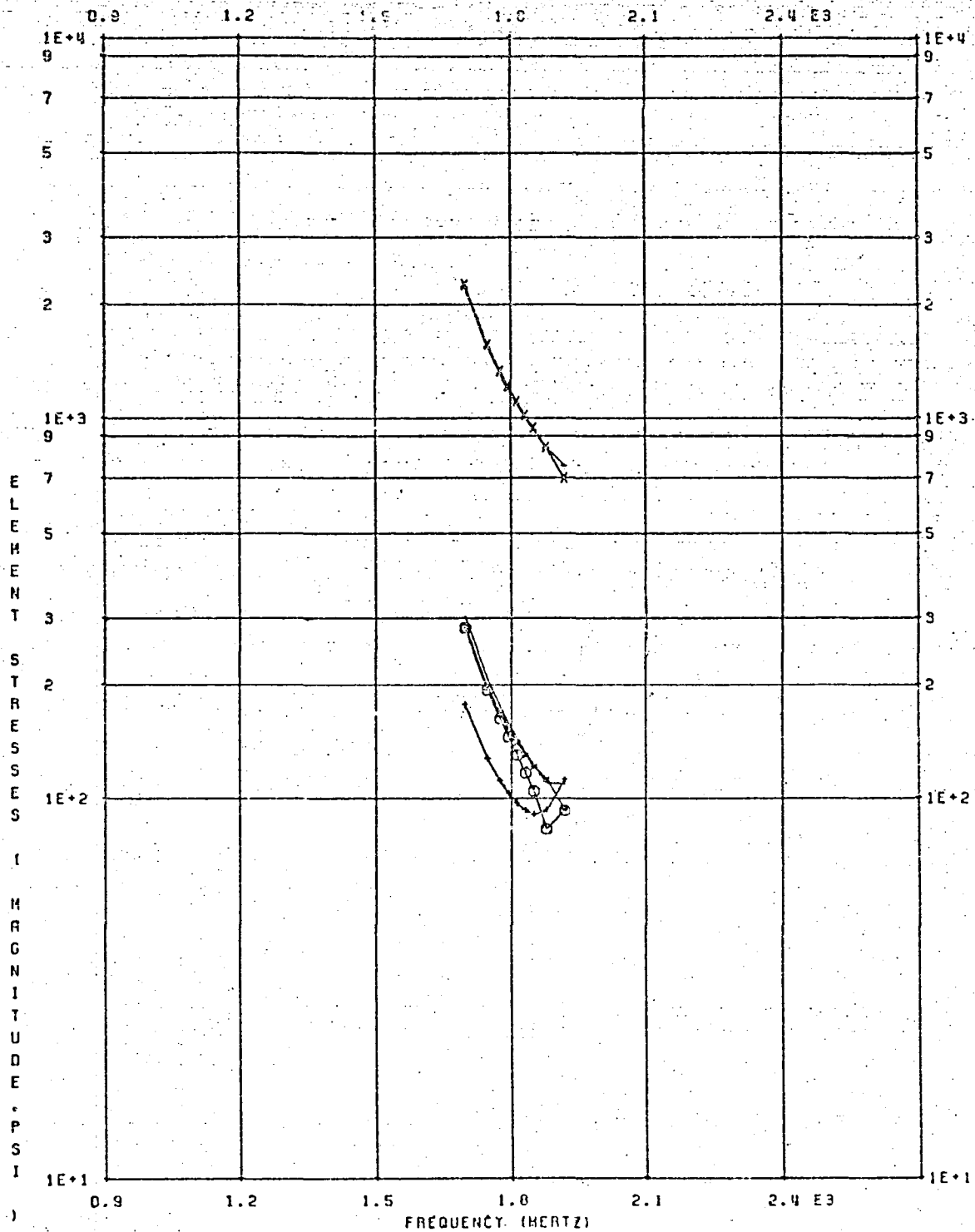
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0 (T3RM), 10 (T3RM)
 FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
 BLADED DISC EXAMPLE 3 (CYC MODEL, FREQ+BASE ACCN LOAD, HARM 1/0
 KINDX 0 SUBCASE 1

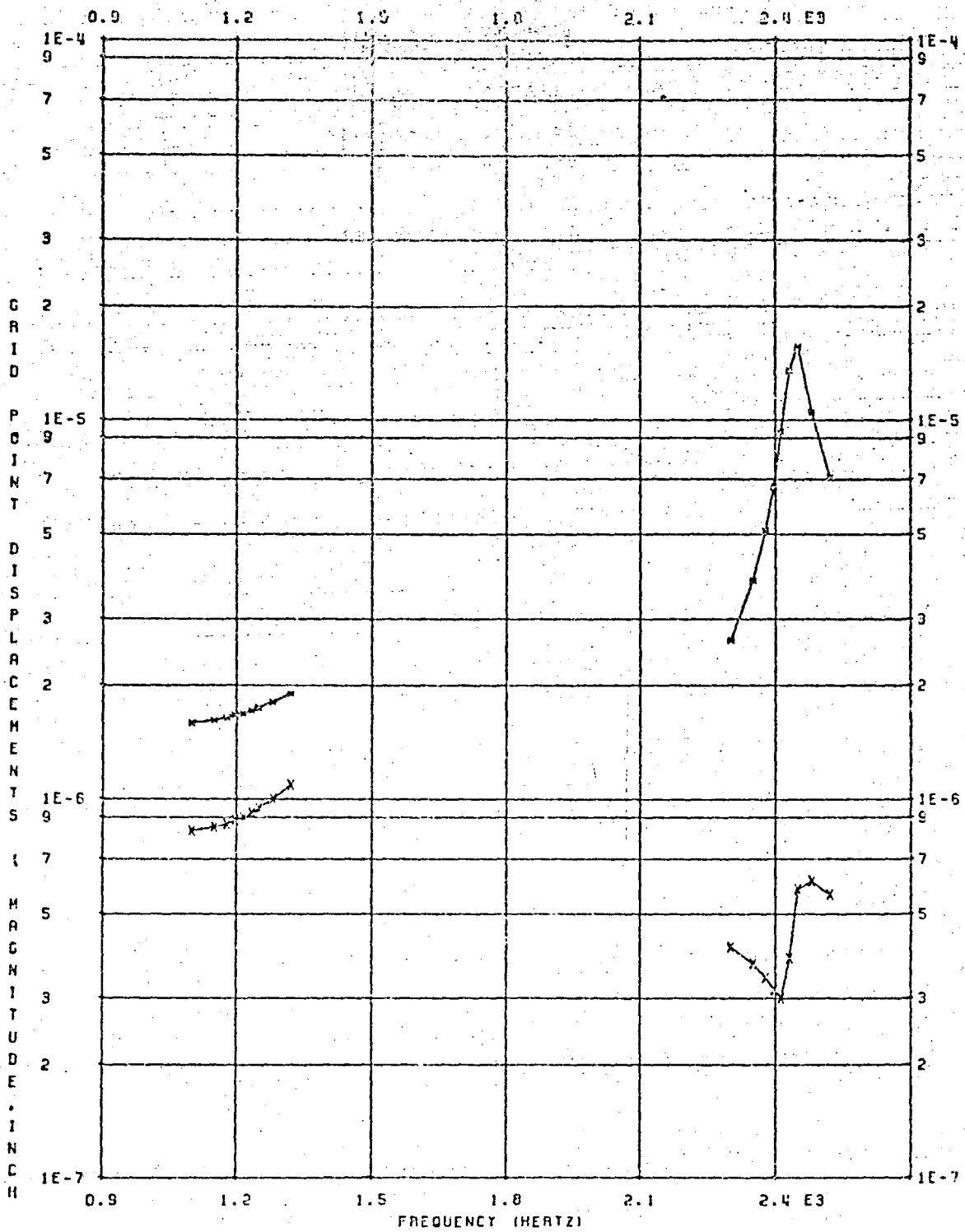
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 FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
 BLADED DISC EXAMPLE 3 (CYC MODEL, FREQ+BASE ACCH LOAD, HARM 1/O
 KINDEX 0 SUBCASE 1

Figure 13

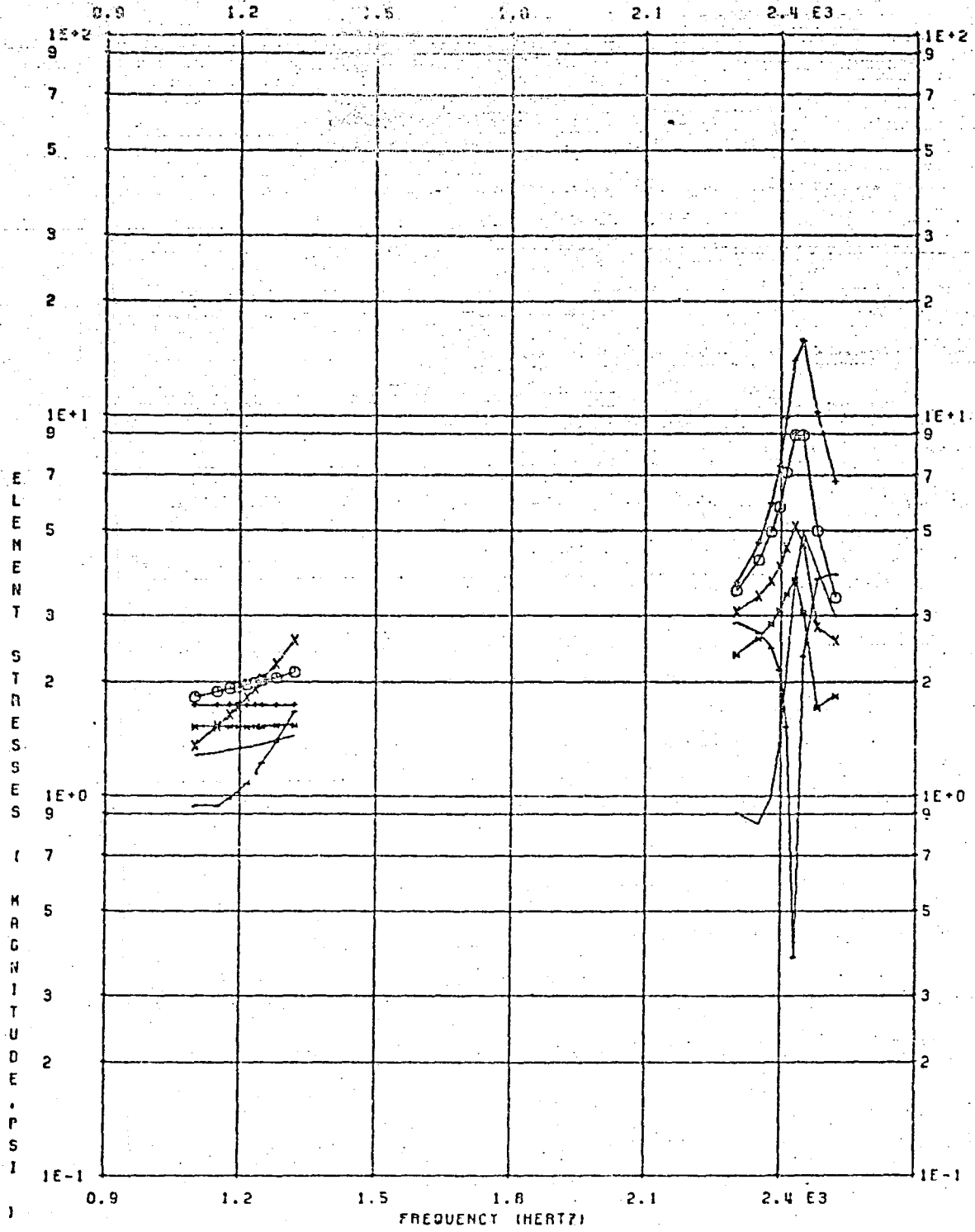


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 FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
 BLADED DISC EXAMPLE 3 (CYC MODEL,FREQ+BASE ACCN LOAD,HARM 1/0
 KINDX 1C SUBCASE 2

Figure 14

(A)

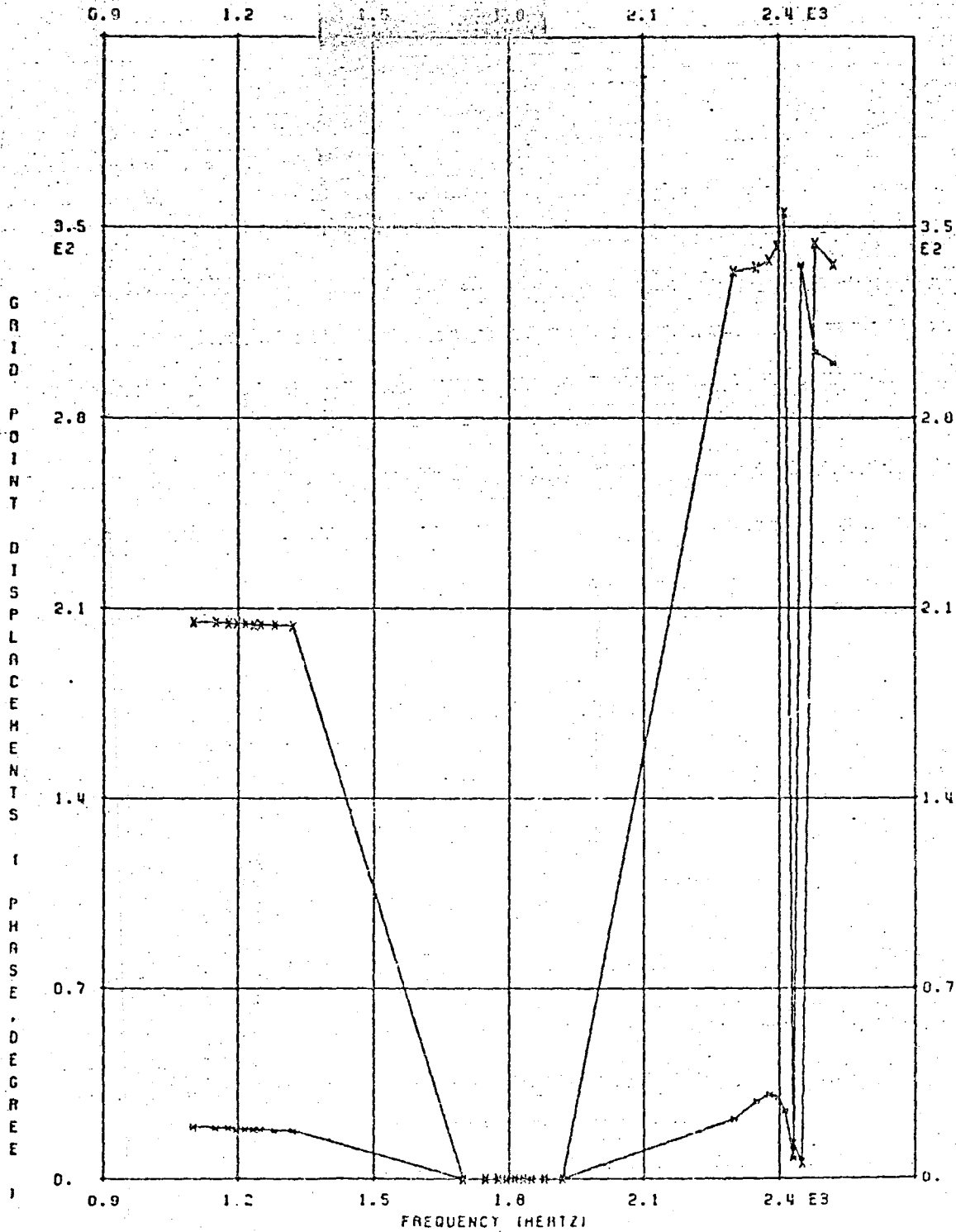
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 FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
 BLADED DISC EXAMPLE 3 (CYC MODEL, FREQ+BASE ACCN LOAD, HARM 1/0
 KINDEX 1C SUBCASE 2

Figure 15

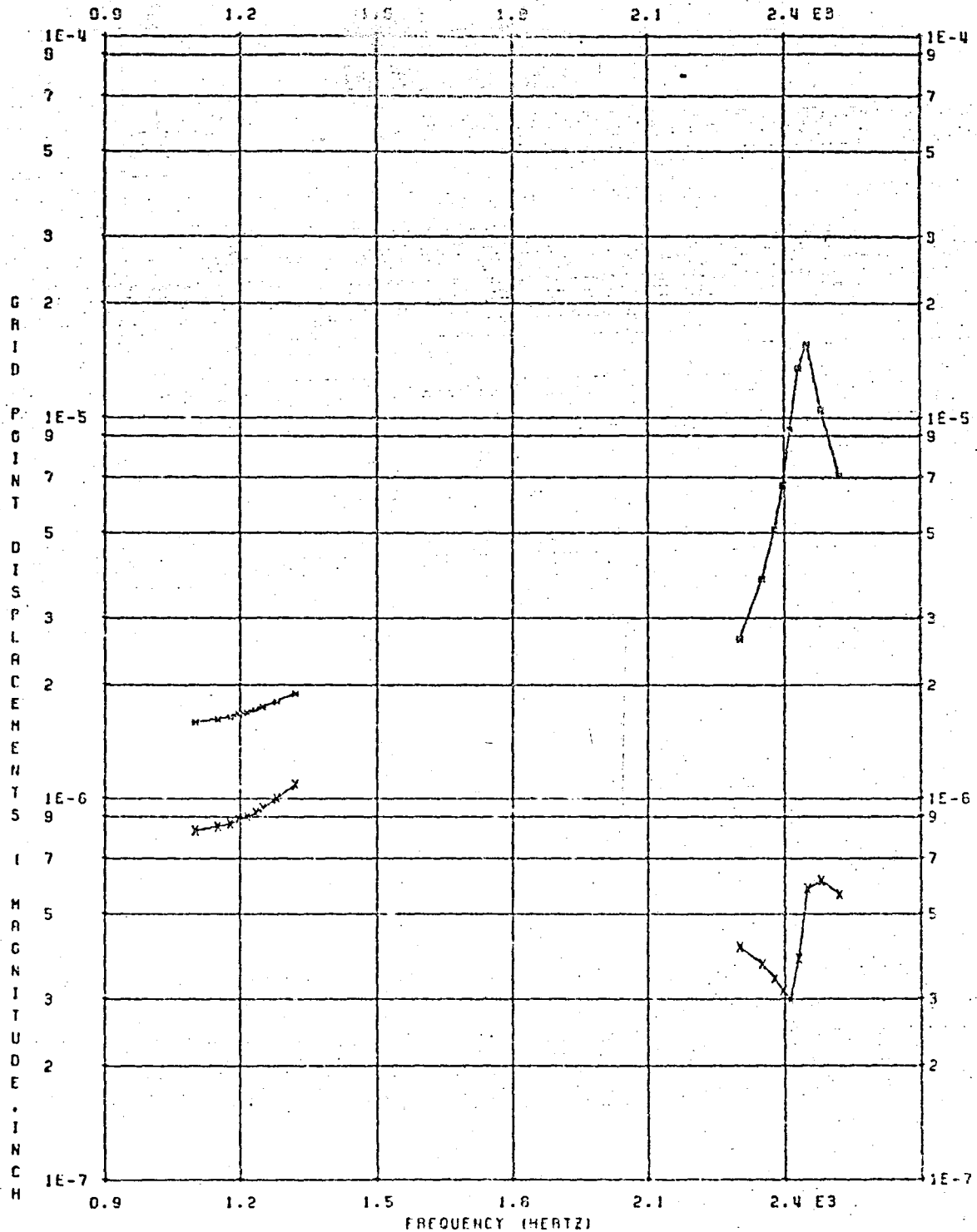
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8 (T3IP), 10 (T3IP)
 FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
 BLADED DISC EXAMPLE 3 (CYC MODEL, FREQ+BASE ACCN LOAD, HARM 1/0
 K:INDEX 1C SUBCASE 2

Figure 16

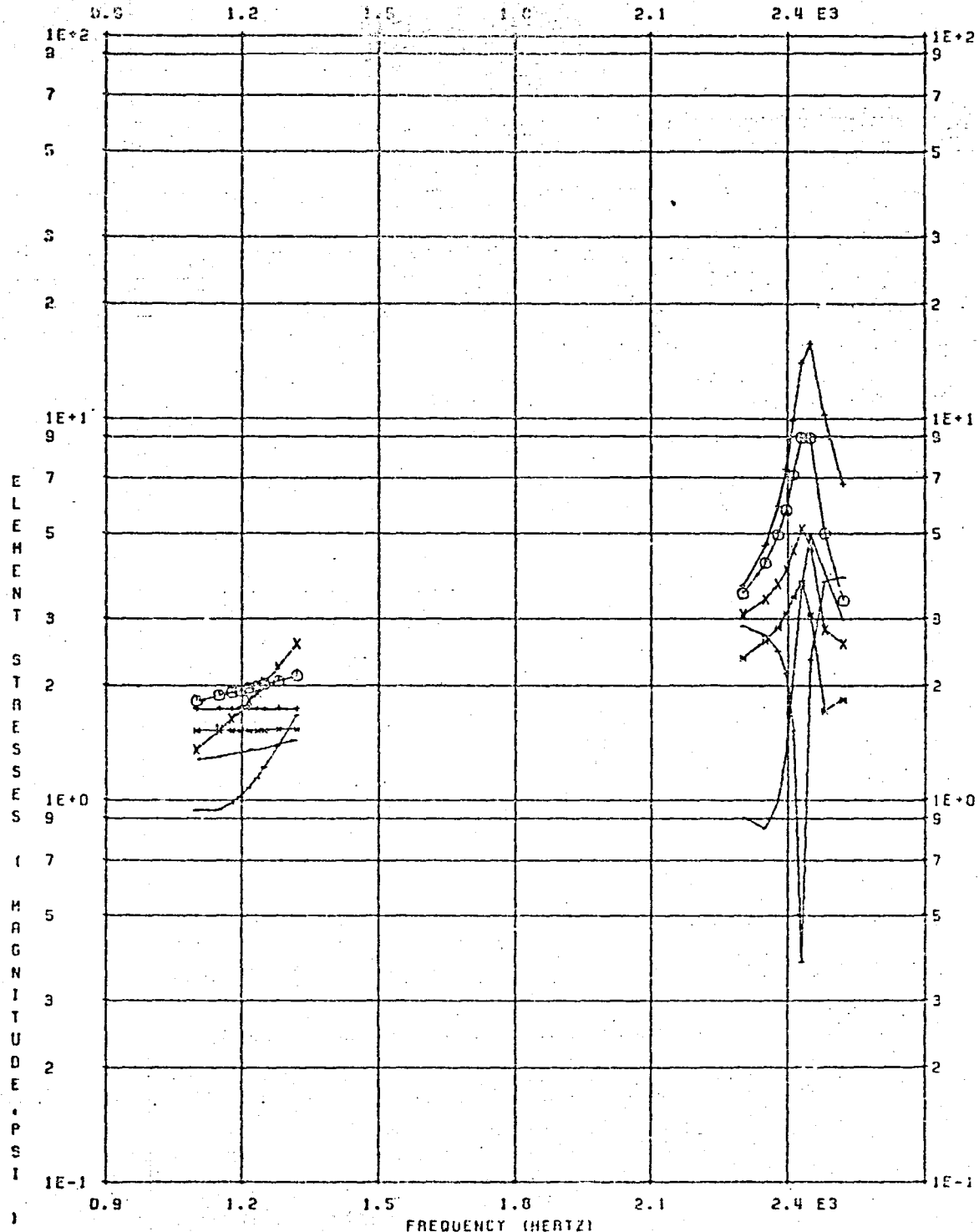
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8 (T3RM), 18 (T3RM)
FORCED VIBRATION ANALYSIS OF ROTATING CYCLIC STRUCTURES
BLADED DISC EXAMPLE 3 (CYC MODEL, FREQ+BASE ACCN LOAD, HARM 1/0
KINDEX 15 SUBCASE 3

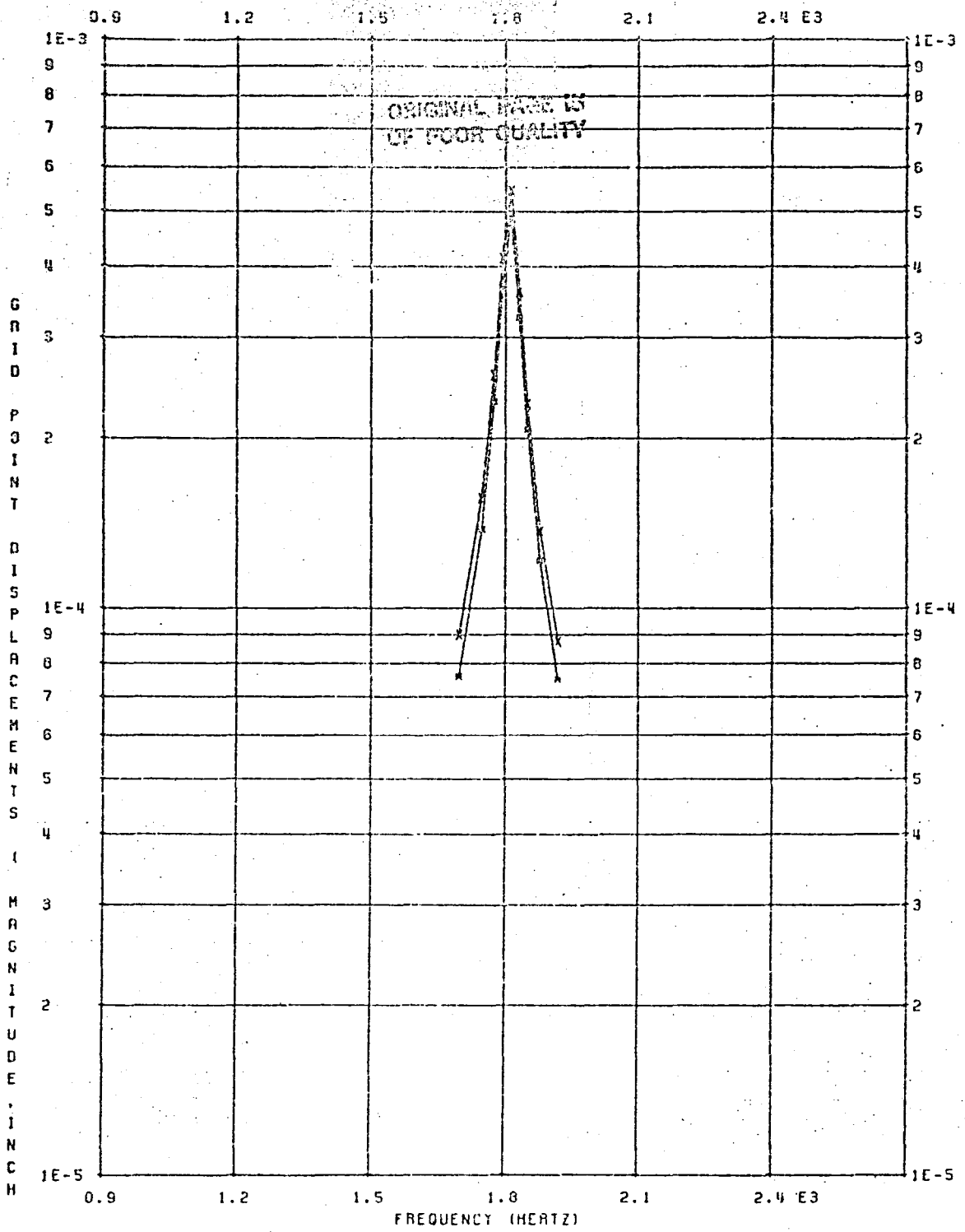
Figure 17

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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 ROCK LOAD, HARM 1/0
 INDEX 15 SUBCASE 3

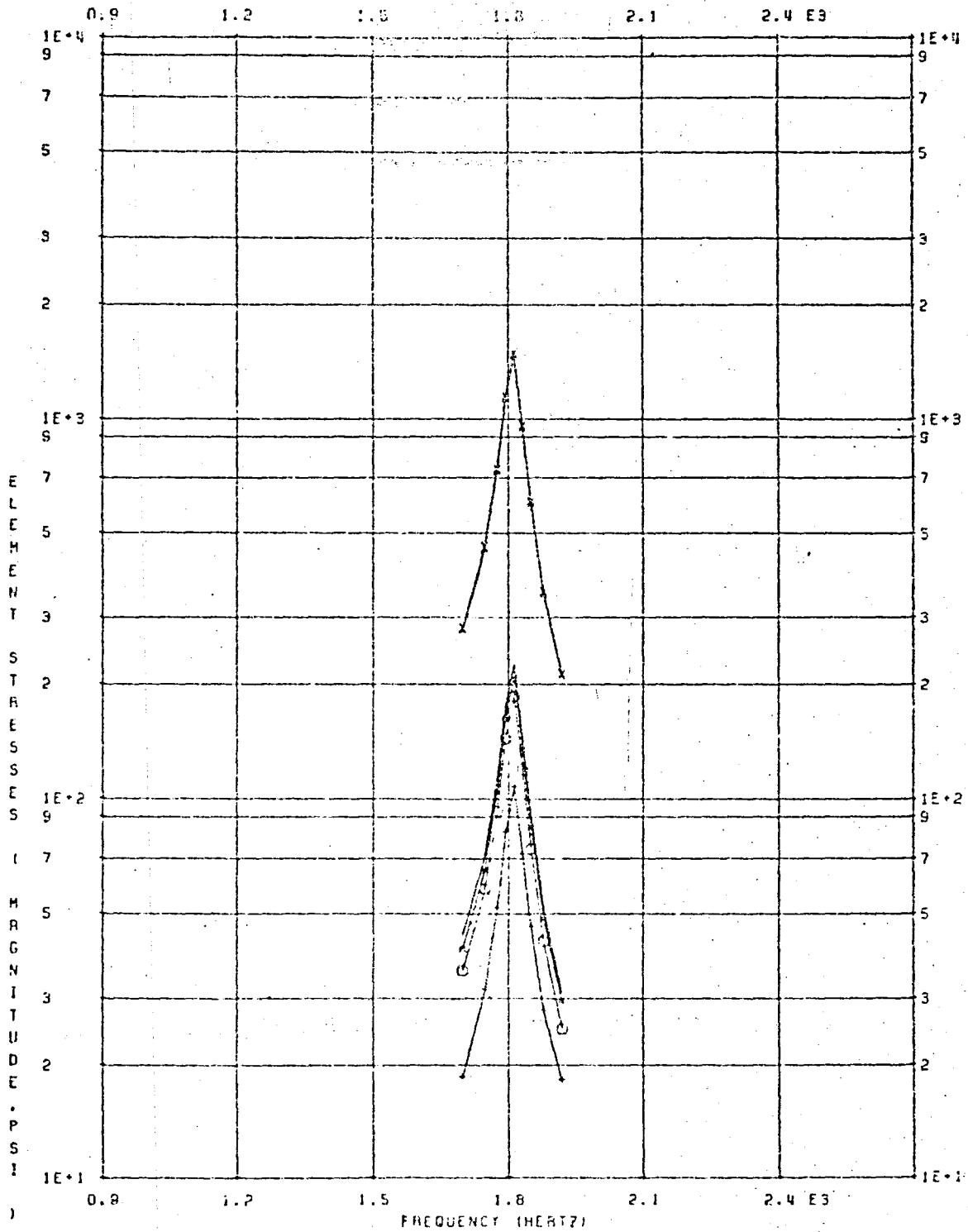
Figure 18



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

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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/C
 KINDX 2C SUBCASE 4)

Figure 20

