OBTAINING EIGENSOLUTIONS FOR MULTIPLE FREQUENCY RANGES IN A SINGLE NASTRAN EXECUTION

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SUMMARY

A novel and general procedure for obtaining eigenvalues and eigenvectors for multiple frequency ranges in a single NASTRAN execution is presented. The scheme is applicable to normal modes analyses employing the FEER and Inverse Power methods of eigenvalue extraction. The procedure is illustrated by examples.

INTRODUCTION

NASTRAN currently offers four methods for real eigenvalue extraction. They are the Tridiagonal or Givens method, the Tridiagonal Reduction or FEER method, the Inverse Power method and the Determinant method (see Section 10 of Reference 1 for details).

The Givens method is a transformation method that computes all of the eigenvalues in a problem; in addition, eigenvectors corresponding to a specified range of frequencies or to a specified number of lowest eigenvalues can also be computed. The FEER method is also a transformation method that allows for the extraction of a specified number of eigensolutions. It requires the specification of a "shift point" or frequency around which the eigensolutions are desired. The Inverse Power and Determinant methods are both tracking methods that allow for the extraction of a specified number of eigensolutions. They both require the specification of a frequency range for which the eigensolutions are desired.

When all, or almost all, of the eigenvalues in a problem are required, the Givens method is the generally the most efficient method to use because the total effort is not highly dependent upon the number of eigenvalues that are extracted. However, when the order of the problem exceeds a few hundred, this method may require prohibitively time-consuming out-of-core operations, thereby losing its efficiency.

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If an user is not interested in obtaining all of the modes in a problem, but only in a smaller number of eigensolutions around a certain frequency or within a certain frequency range, the FEER, the Inverse Power and the Determinant methods are the obvious choices. The computations in all of these methods are proportional to the number of eigensolutions extracted. The FEER method is probably the most efficient of the three. It is quite effective in obtaining eigensolutions around the selected frequency. It is also very efficient even when out-of-core operations are involved. The results obtained by the Inverse Power and Determinant methods, on the other hand, are very susceptible to the number of estimated roots specified for a given frequency range (field 5 on the EIGR bulk data card; see Reference 2). When the specified number for the estimated roots is larger than the actual number of roots in that range, these methods are apt to yield many lower frequencies outside the specified frequency range. The Determinant method is the least efficient of all of the methods and will, therefore, not be considered any further for the purpose of this paper.

CURRENT PROCEDURE FOR OBTAINING EIGENSOLUTIONS FOR MULTIPLE FREQUENCY RANGES

There are practical situations in which an user may be interested in obtaining eigensolutions for multiple frequency ranges, with one frequency range quite distinct and apart from another frequency range. Complex configurations involving control systems, experimental setups and structural subsystems are examples of such situations.

None of the eigenvalue extraction methods discussed earlier can accomplish the above objective directly. So, if the user wishes to obtain eigenvalues for more than one range of frequencies in such cases as the above, he can accomplish it at present in one of two ways. The first way is for the user to make a single NASTRAN execution with a large frequency range (or a shift point in conjunction with a large number of desired roots) so as to encompass all of the frequencies in the ranges of interest. However, this will not be very cost effective if the frequency ranges of interest are widely separated. The alternative way is for the user to perform multiple NASTRAN executions, one execution for each range of frequencies, effectively utilizing the APPEND feature (see Section 9.2.2 in Reference 1 and Section 2.3.7 in Volume 2, Reference 2). However, this latter procedure involves checkpoint/restart runs and is rather cumbersome for the purpose.

PROPOSED PROCEDURE FOR OBTAINING EIGENSOLUTIONS FOR MULTIPLE FREQUENCY RANGES

The above objective of obtaining eigensolutions for multiple frequency ranges can be accomplished in a single NASTRAN execution by an innovative procedure that involves the use of DMAP ALTERs in conjunction with certain specific input data requirements. This procedure involves performing a normal modes analysis employing multiple subcases and using the FEER method or the Inverse Power method (whichever is preferred). Each subcase is setup so as to obtain eigensolutions in a specified frequency range. The final results of the analysis will contain the eigensolutions obtained in all of the specified frequency ranges. This procedure is, in essence, a novel application of the APPEND feature referred to above. The important difference is that, while the APPEND feature was originally conceived to be employed in a checkpoint/restart environment, the proposed procedure accomplishes this in a single NASTRAN execution.

The DMAP ALTER package required for the above procedure is given in Appendix A. The details of the input data requirements and the output obtained from the analysis are discussed below.

Executive Control Deck

The user should employ the DMAP ALTER package given in Appendix A either by explicitly including it or by referencing it via a READFILE card in the Executive Control Deck. Note that, for every additional subcase beyond the first subcase, the ALTER package involves a pair of OFP and READ modules.

Case Control Deck

The user should have as many subcases in the Case Control Deck as the number of distinct frequency ranges for which he wishes to obtain eigensolutions. Each subcase must have a separate METHOD request. The METHOD request in each subcase references a distinct EIGR card in the Bulk Data Deck that either implies (in the case of the FEER method) or defines (in the case of the Inverse Power method) a distinct frequency range.

All output requests and constraint specifications must be above the subcase level. Thus, the only difference between one subcase and another must be the different METHOD that they request. Also, since the final results include eigensolutions for all of the subcases, PLOT requests should not make explicit references to subcase numbers.

Bulk Data Deck

In addition to the required modeling (geometry, constraints, etc.) data, the Bulk Data Deck should have as many EIGR cards as the number of subcases employed (and the corresponding METHOD requests) in the Case Control setup.

When using the FEER method, the EIGR bulk data card for each METHOD request requires the specification of a shift point or frequency that indicates the center of a frequency range as well as the number of desired roots (see Reference 2). The user should specify appropriate values accordingly. The shift point specified has a significant effect on the actual eigensolutions extracted. Accordingly, depending upon the shift point specified, the actual number of roots computed may be more or less than the number of desired roots specified in the data.

When using the Inverse Power method, the EIGR bulk data card for each METHOD request requires the specification of a frequency range, the number of desired roots as well as the number of estimated roots in the specified frequency range (see Reference 2). The number of estimated roots specified has a significant effect on the actual eigensolutions extracted. However, the user, in general, will not have an a priori idea of the actual number of eigenvalues that may exist in a particular frequency range. Accordingly, the user should use his best judgment to specify this number. A number for the estimated roots that is larger than the actual number of roots in that range will, in general, yield a number of lower frequencies that are outside the specified frequency range.

It should also be noted here the eigensolutions resulting from any particular subcase will include not only the eigensolutions that are computed in that subcase, but also the eigensolutions resulting

from all previous subcases. Accordingly, regardless of which eigenvalue extraction method is employed, the number of desired roots specified on the EIGR card for a particular subcase must allow not only for the roots that will be computed by that subcase, but also include the roots computed by all of the previous subcases.

Output from the Analysis

As mentioned earlier, the final results from the analysis will include the eigensolutions for all of the subcases specified in the Case Control Deck setup. The DMAP ALTER package given in Appendix A also generates the eigenvalue summary table and the eigenvalues for all of the subcases of the analysis. If the user so desires, he can suppress any of these intermediate results by commenting out the OFP modules corresponding to those subcases (see Appendix A). Also, for every subcase, the program indicates the number of roots from all previous subcases that are included in that subcase.

EXAMPLES

Two examples were set up to illustrate the procedure discussed above. Details are given below. All of the runs were made on RPK's CRAY version of NASTRAN.

Example 1

The standard NASTRAN Demonstration Problem No. D10-02-1A (see Reference 3) was selected for this example. This problem employs the Givens method for eigenvalue extraction. The cyclic frequencies obtained for this case are presented in Table 1.

This problem was then modified to use the Inverse Power method and eigensolutions for two frequency ranges (500.0 - 1000.0 hertz and 20000.0 - 30000.0 hertz) were requested using the procedure described above. The input data setup is given in Appendix B.

The cyclic frequencies obtained for this case are presented in Table 2. It can be seen that these frequencies are subsets of those in Table 1.

Example 2

A variation of NASTRAN Demonstration Problem No. D03-08-1A (without any SUPORT data) (see Reference 3) was selected for this example. This problem also employs the Givens method for eigenvalue extraction. The cyclic frequencies obtained for this case are presented in Table 3.

This problem was then modified to use the FEER method and eigensolutions around three shift points or frequencies (100.0 hertz, 1500.0 hertz and 5300.0 hertz) were requested using the procedure described above. The input data setup is given in Appendix C.

The cyclic frequencies obtained for this case are presented in Table 4. It can be seen that these frequencies are subsets of those in Table 3.

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The results of the above examples clearly demonstrate the validity and usefulness of the proposed method.

ACKNOWLEDGMENT

CONCLUDING REMARKS

A novel procedure for obtaining eigenvalues and eigenvectors for multiple frequency ranges in a single NASTRAN execution is presented. The scheme is applicable to normal modes analyses employing the FEER and Inverse Power methods of eigenvalue extraction. The procedure is illustrated by examples. The procedure should be particularly helpful in large problems with widely separated frequency ranges.

REFERENCES

1. The NASTRAN Theoretical Manual, NASA SP-221(06), January 1981.

2. The NASTRAN User's Manual, NASA SP-222(08), June 1986.

3. The NASTRAN Demonstration Problem Manual, NASA SP-224(05), December 31, 1978 Edition, Reprinted September 1983.

DMAP ALTERs for Obtaining Eigensolutions for Multiple

Frequency Ranges in a Single NASTRAN Execution

```
$***********************************************************
$ THE FOLLOWING ALTERS ARE FOR DISPLACEMENT RIGID FORMAT 3
$ (NORMAL MODES ANALYSIS).  SIMILAR ALTERS WILL WORK FOR
$  OTHER RIGID FORMATS THAT INVOLVE REAL EIGENVALUE
$ EXTRACTION.
$
$ NOTE THAT, FOR EVERY SUBCASE BEYOND THE FIRST SUBCASE, THE
$ ALTERS BELOW INVOLVE A PAIR OF OFP AND READ MODULES.
$***********************************************************
$
$ INSERT AFTER THE READ MODULE IN THE RIGID FORMAT
$
INSERT   READ $ ON RPK-SUPPORTED VERSIONS
$ USE ALTER 70 $ ON 1989 COSMIC-SUPPORTED VERSIONS
$ USE OF ALTER 70 $ IS ALSO PERMITTED ON RPK-SUPPORTED VERSIONS
$
$ USE THE FOLLOWING OFP STATEMENT TO REQUEST THE EIGENVALUE
$ SUMMARY TABLE AND THE EIGENVALUES THAT ARE AUTOMATICALLY
$ OBTAINED BY THE RIGID FORMAT FOR THE FIRST SUBCASE
$
OFP       OEIGS,LAMA,,,,//S,N,CARDNO $
$
$ COMPUTE THE EIGENSOLUTIONS FOR THE SECOND SUBCASE
$ (THE LAST PARAMETER 2 IN THE FOLLOWING READ MODULE
$ INDICATES THAT THE ANALYSIS IS FOR THE SECOND SUBCASE)
$
READ      KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/
          *MODES*/S,N,NEIGV/2 $
$
$ USE THE FOLLOWING OFP STATEMENT TO REQUEST THE EIGENVALUE
$ SUMMARY TABLE AND THE EIGENVALUES FOR THE SECOND SUBCASE
$ (THE RESULTS WILL INCLUDE THE RESULTS FOR THE FIRST SUBCASE)
$
OFP       OEIGS,LAMA,,,,//S,N,CARDNO $
$
$ COMPUTE THE EIGENSOLUTIONS FOR THE THIRD SUBCASE
$ (THE LAST PARAMETER 3 IN THE FOLLOWING READ MODULE
$ INDICATES THAT THE ANALYSIS IS FOR THE THIRD SUBCASE)
$
```

```
READ      KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/
          *MODES*/S,N,NEIGV/3 $
$
$ USE THE FOLLOWING OFP STATEMENT TO REQUEST THE EIGENVALUE
$ SUMMARY TABLE AND THE EIGENVALUES FOR THE THIRD SUBCASE
$ (THE RESULTS WILL INCLUDE THE RESULTS FOR THE FIRST AND
$ SECOND SUBCASES)
$
OFP       OEIGS,LAMA,,,,//S,N,CARDNO $
   .
   .
   .
   .
   .

$
$ COMPUTE THE EIGENSOLUTIONS FOR THE LAST SUBCASE
$ (THE LAST PARAMETER n IN THE FOLLOWING READ MODULE
$ SHOULD BE AN INTEGER VALUE CORRESPONDING TO THE LAST
$ SUBCASE, INDICATING THAT THE ANALYSIS IS FOR THE LAST SUBCASE)
$
$ THE FINAL RESULTS (WHICH INCLUDE THE RESULTS FOR ALL OF THE
$ SUBCASES) ARE AUTOMATICALLY OUTPUT BY THE RIGID FORMAT
$
READ      KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/
          *MODES*/S,N,NEIGV/n $
$
CASE      CASECC,/CASEXX/*TRAN* $
EQUIV     CASEXX,CASECC $
ENDALTER $
```

APPENDIX B

Input Data Setup for NASTRAN Demonstration Problem

No. D10-02-1A Modified to Use the Procedure Described

in the Paper

```
ID ...
.
.
READFILE alters
.
.
CEND
.
.
SUBCASE 10
      METHOD = 100
SUBCASE 20
      METHOD = 200
.
.
BEGIN BULK
.
.
EIGR,100,INV,500.0,1000.0,5,5,,,+EIG1
+EIG1,MAX
EIGR,200,INV,20000.0,30000.0,10,10,,,+EIG2
+EIG2,MAX
.
.
ENDDATA
```

APPENDIX C

Input Data Setup for NASTRAN Demonstration Problem

No. D03-08-1A (Without Any SUPORT Data) Modified to

Use the Procedure Described in the Paper

ID ...

.

.

READFILE alters

.

.

CEND

.

.

SUBCASE 11
        METHOD = 1001
SUBCASE 21
        METHOD = 2001
SUBCASE 31
        METHOD = 3001

.

.

BEGIN BULK

.

.

EIGR,1001,INV,100.0,,,5,,,+EIG1
+EIG1,MAX
EIGR,2001,INV,1500.0,,,10,,,+EIG2
+EIG2,MAX
EIGR,3001,INV,5300.0,,,12,,,+EIG3
+EIG3,MAX

.

.

ENDDATA

TABLE 1

Natural Frequencies for NASTRAN Demonstration No. D10-02-1A

Mode No.	Cyclic Frequency (Hz)
1	3.996147E+01
2	2.364137E+02
3	2.504423E+02
4	7.014011E+02
5	7.034198E+02
6	1.153105E+03
7	1.375429E+03
8	1.574398E+03
9	1.956923E+03
10	2.277239E+03
11	2.291261E+03
12	2.569183E+03
13	2.783842E+03
14	2.929954E+03
15	3.003921E+03
16	3.411562E+03
17	4.786588E+03
18	6.412708E+03
19	8.291552E+03
20	1.030759E+04
21	1.371895E+04
22	1.657422E+04
23	2.009181E+04
24	2.424947E+04
25	2.913932E+04
26	3.485085E+04
27	4.136255E+04
28	4.828881E+04
29	5.437856E+04
30	6.805413E+04

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TABLE 2

Natural Frequencies for NASTRAN Demonstration
No. D10-02-1A Modified to Use the Procedure
Described in the Paper

Computed Mode No.	Corresponding Mode No. in Table 1	Cyclic Frequency (Hz)	Subcase in Which Computed (See Appendix B)
1	2	2.364137E+02	First
2	3	2.504423E+02	First
3	4	7.014011E+02	First
4	5	7.034198E+02	First
5	22	1.657422E+04	Second
6	23	2.009181E+04	Second
7	24	2.424947E+04	Second
8	25	2.913932E+04	Second
9	26	3.485085E+04	Second

TABLE 3

Natural Frequencies for NASTRAN
Demonstration No. D03-08-1A
(Without Any SUPORT Data)

Mode No.	Cyclic Frequency (Hz)
1	7.341481E-04
2	4.168523E-04
3	6.790643E-05
4	1.505714E-04
5	2.765971E-04
6	6.434454E-04
7	2.987344E+00
8	3.372945E+00
9	2.447569E+01
10	2.682217E+01
11	6.154903E+01
12	7.034309E+01
13	1.133579E+02
14	1.174531E+02
15	1.646037E+02
16	2.902883E+02
17	2.905903E+02
18	4.508246E+02
19	4.515298E+02
20	6.945689E+02
21	6.953026E+02
22	8.685333E+02
23	9.752645E+02
24	9.752699E+02
25	1.343024E+03
26	1.344180E+03
27	1.466313E+03
28	1.569195E+03
29	1.912914E+03
30	1.918371E+03
31	2.025981E+03
32	2.446537E+03
33	2.446840E+03
34	2.458828E+03
35	2.742675E+03
36	2.971822E+03
37	3.918531E+03
38	3.918534E+03
39	4.451851E+03
40	6.261906E+03
41	8.528055E+03

TABLE 4

Natural Frequencies for NASTRAN Demonstration
No. D03-08-1A (Without Any SUPORT DATA) Modified
to Use the Procedure Described in the Paper

Computed Mode No.	Corresponding Mode No. in Table 3	Cyclic Frequency (Hz)	Subcase in Which Computed (See Appendix C)
1	9	2.447569E+01	First
2	10	2.682217E+01	First
3	11	6.154903E+01	First
4	12	7.034309E+01	First
5	13	1.133579E+02	First
6	14	1.174531E+02	First
7	25	1.343024E+03	Second
8	26	1.344180E+03	Second
9	27	1.466313E+03	Second
10	28	1.569195E+03	Second
11	39	4.451851E+03	Third
12	40	6.261906E+03	Third