Code_Aster

Version default

Operator MODE_ITER_INV

1 Goal

That that is to study the vibrations of a structure (possibly deadened or revolving) or to search its modes of buckling, the mechanic must often solve a modal problem: that is to say **generalized (GEP)** [R5.01.01], that is to say **quadratic (QEP)** [R5.01.02]. With this intention, *Code_Aster* propose two core operators: MODE_ITER_SIMULT and MODE_ITER_INV.

first operator is rather to use when one seeks a significant part of the spectrum (methods of subspace or global method). The second operator, who is the object of this note, is to be privileged when one is interested in only some clean modes (typically a half-dozen) or when one wishes to possibly refine some estimates (coming from MODE_ITER_SIMULT).

MODE_ITER_INV determine the clean modes in two stages: a preliminary phase of localization of the eigenvalues followed by an improvement of these estimates and calculation of their associated own vectors.
first stage bases itself only on evaluations provided by the user or refines them by the heuristic ones adapted: in GEP, by a technique of bisection possibly supplemented by a method of the secant; in QEP, by a method of Müller-Traub. **The second stage** met of work an algorithm of the type powers opposite: in GEP, the standard method possibly accelerated by a coefficient of Rayleigh; in QEP, an alternative due to Jennings.

This operator produces one **concept** mode_meca_* (dynamic case) or mode_flamb (case buckling of Euler, only in GEP) according to the value indicated in the keyword TYPE_RESU. **perimeter of use** of MODE_ITER_INV limits itself to the GEP and the QEP with real symmetrical matrices.
This document describes the parameters accessible from each method specific to the operator MODE_ITER_INV.

For optimized performances CPU, this operator can be used with the parallelism of linear solvor MUMPS.

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Version default

Date : 28/10/2014 Page : 2/19
Clé : U4.52.04 Révision :
d2a45b254b1d

Contents

Code_Aster

Version
default

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Date : 28/10/2014 Page : 3/19
Clé : U4.52.04
Révision :
d2a45b254b1d

2 Syntax

```
mode  [*] =MODE_ITER_INV

# STANDARD OF PROBLEM
    ◊   'DYNAMIC' TYPE_RESU=/                                    [DEFECT]
                  /'MODE_FLAMB' (only in GEP)
                  /'GENERAL'

# IF TYPE_RESU= 'DYNAMIQUE'

    (  ♦  MATR_RIGI=A                           /[matr_asse_DEPL_R]
                                                /[matr_asse_PRES_R]
                                                /[matr_asse_GENE_R]
       ♦  MATR_MASS=B                           /[matr_asse_DEPL_R]
                                                /[matr_asse_PRES_R]
                                                /[matr_asse_GENE_R]
    ◊  MATR_AMOR=C  (only in QEP)          [matr_asse_DEPL_R]

    ♦  CALC_FREQ=_F ( ◊ OPTION=   /'NEAR'         (not of multiple mode)
                                  /'SEPARATE'             (only in GEP)
                                  /'ADJUSTS'     [DEFECT]
                      ♦ FREQ=lfreq        [l_R]
                      ◊ AMOR_REDUIT=lamor [l_R]
                      ◊ NMAX_FREQ=  /0    [DEFECT]
                                    /nf   [I]

        #  IF OPTION= 'SEPARE' or 'ADJUSTS' (only in GEP)
                      ◊ NMAX_ITER_SEPARE=  /30  [DEFECT]
                                           /nis [I]
                      ◊ PREC_SEPARE= /1.E-4     [DEFECT]
                                     /ps        [R]

        #  IF OPTION= 'AJUSTE'
                      ◊ NMAX_ITER_AJUSTE=/15     [DEFECT]
                                         /nia    [I]
                      ◊ PREC_AJUSTE= /1.E-4       [DEFECT]
                                     /pa          [R]
# FOR PRE AND POSTPROCESSINGS
                      ◊ SEUIL_FREQ=  /1.E-2      [DEFECT]
                                     /sf         [R]
                      ◊ PREC_SHIFT=  /0.05       [DEFECT]
                                     /ps         [R]
                      ◊ NMAX_ITER_SHIFT=/3       [DEFECT]
                                        /ns      [I]


# IF TYPE_RESU= 'MODE_FLAMB' (only in GEP)

    (  ♦  MATR_RIGI=A                           /[matr_asse_DEPL_R]
                                                /[matr_asse_PRES_R]
                                                /[matr_asse_GENE_R]
       ♦  MATR_RIGI_GEOM=B                      /[matr_asse_DEPL_R]
                                                /[matr_asse_PRES_R]
                                                /[matr_asse_GENE_R]

    ♦  CALC_CHAR_CRIT=_F ( ◊ OPTION=     /'NEAR'    (not of multiple mode)
                                         /'SEPARATE'         (only in GEP)
                                         /'ADJUSTS'   [DEFECT]
```

Code_Aster

Version default

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Date : 28/10/2014 Page : 4/19
Clé : U4.52.04 Révision :
d2a45b254b1d

```
                              ♦ CHAR_CRIT=lchar              [l_R]
                              ◊ NMAX_CHAR_CRIT=/0            [DEFECT]
                                              /nf            [I]


              #   IF OPTION= 'SEPARE' or 'ADJUSTS' (only in GEP)
                              ◊ NMAX_ITER_SEPARE=   /30      [DEFECT]
                                                    /nis     [I]
                              ◊ PREC_SEPARE= /1.E-4          [DEFECT]
                                             /ps             [R]

              #   IF OPTION= 'AJUSTE'
                              ◊ NMAX_ITER_AJUSTE=/15         [DEFECT]
                                                /nia         [I]
                              ◊ PREC_AJUSTE= /1.E-4          [DEFECT]
                                             /pa             [R]
         # FOR PRE AND POSTPROCESSINGS
                              ◊ SEUIL_CHAR_CRIT=/1.E-2       [DEFECT]
                                               /sf          [R]
                              ◊ PREC_SHIFT=  /0.05          [DEFECT]
                                             /ps            [R]
                              ◊ NMAX_ITER_SHIFT= /3          [DEFECT]
                                                /ns          [I]

      #   IF TYPE_RESU= 'GENERAL'
        ( ♦ MATR_A=A                              /[matr_asse_DEPL_R]
                                                  /[matr_asse_PRES_R]
                                                  /[matr_asse_GENE_R]
          ♦ MATR_B=B                              /[matr_asse_DEPL_R]
                                                  /[matr_asse_PRES_R]
                                                  /[matr_asse_GENE_R]


          ♦ CALC_CHAR_CRIT=_F ( ◊ OPTION=    /'NEAR'     (not of multiple mode)
                                             /'SEPARATE'     (only in GEP)
                                             /'ADJUSTS'  [DEFECT]
                              ♦ CHAR_CRIT=lchar            [l_R]
                              ◊ NMAX_CHAR_CRIT=/0          [DEFECT]
                                              /nf          [I]

              #   IF OPTION= 'SEPARE' or 'ADJUSTS' (only in GEP)
                              ◊ NMAX_ITER_SEPARE=   /30    [DEFECT]
                                                    /nis   [I]
                              ◊ PREC_SEPARE=  /1.E-4       [DEFECT]
                                              /ps          [R]

              #   IF OPTION= 'AJUSTE'
                              ◊ NMAX_ITER_AJUSTE=/15        [DEFECT]
                                                /nia        [I]
                              ◊ PREC_AJUSTE= /1.E-4         [DEFECT]
                                             /pa            [R]
         # FOR PRE AND POSTPROCESSINGS
                              ◊ SEUIL_CHAR_CRIT=/1.E-2      [DEFECT]
                                               /sf         [R]
                              ◊ PREC_SHIFT=/0.05           [DEFECT]
                                           /ps             [R]
                              ◊ NMAX_ITER_SHIFT=/3          [DEFECT]
                                               /ns          [I]
```

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Version
default

Date : 28/10/2014 Page : 5/19
Clé : U4.52.04
Révision :
d2a45b254b1d

#**PARAMETRAGE PHASE ITERATIONS OPPOSITE**

```
        ◊   CALC_MODE=_F (  ◊  OPTION=/'DIRECT'                  [DEFECT]
                                   /'RAYLEIGH'  (only in GEP)
                         ◊   NMAX_ITER=/30                       [DEFECT]
                                     /nim                        [I]
                        ◊   PREC=/1.E-5                          [DEFECT]
                              /pm                                [R]
                       )
```

#**FOR FINAL CHECKING**

```
        ◊   VERI_MODE=_F (  ◊   STOP_ERREUR=/'YES'              [DEFECT]
                                     /'NOT'
                         ◊   SEUIL=/1.E-2                        [DEFECT]
                              /r                                 [R]
                       )
```

#**ANY OTHER BUSINESS**

```
        ◊   INFO=/1                                             [DEFECT]
              /2

        ◊   TITRE=ti                                            [l_Kn]
    );
```

#*RESULTATS OF THE MODAL PROBLEM*

```
    If   TYPE_RESU= 'MODE_FLAMB'        then        [*]   - >mode_flamb
    If   TYPE_RESU= 'GENERAL'           then        [*]   - >mode_flamb
    If   MATR_AMOR or MATR_C= [matr_asse_DEPL_R] then [*]   - >mode_meca_c
    If   MATR_RIGI or MATR_A= [matr_asse_DEPL_R] then [*]   - >mode_meca
    If   MATR_RIGI or MATR_A= [matr_asse_PRES_R] then [*]   - >mode_acou
    If   MATR_RIGI or MATR_A= [matr_asse_GENE_R] then [*]   - >mode_gene
```

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

**Version
default**

Date : 28/10/2014 Page : 6/19
Clé : U4.52.04   Révision   :
d2a45b254b1d

3   Operands

3.1   Principles

This operator solves it **generalized problem (GEP)** with the eigenvalues according to [R5.01.01]:

To find $(\lambda, \mathbf{x})$ such as $\mathbf{A}\mathbf{x} = \lambda \mathbf{B}\mathbf{x}$, $\mathbf{x} \neq 0$, where $\mathbf{A}$ and $\mathbf{B}$ are real, symmetrical matrices or not.

To model a damping hysteretic in the study of the free vibrations of a structure, the matrix $\mathbf{A}$ can be complex symmetrical [U2.06.03] [R5.05.04].

This kind of problem corresponds, in mechanics, in particular with:

- **The study of the free vibrations of a structure** not deadened and nonrevolving. For this structure, one searches the smallest eigenvalues or those which are in an interval given to know if an exiting force can create a resonance. In this case, the matrix $\mathbf{A}$ is the matrix of material rigidity, noted $\mathbf{K}$, symmetrical real (possibly increased geometrical matrix of noted rigidity $\mathbf{K}_g$, if the structure is prestressed), and $\mathbf{B}$ is the matrix of mass or noted inertia $\mathbf{M}$ (symmetrical real). The eigenvalues obtained are the squares of the pulsations associated with the sought frequencies. The system to be solved can be written

$$\underbrace{\left(\mathbf{K} + \mathbf{K}_g\right)}_{\mathbf{A}} \mathbf{x} = \lambda \underbrace{\mathbf{M}}_{\mathbf{B}} \mathbf{x}$$

  where $\lambda = (2\pi f)^2$ is the square of the pulsation ω, f the Eigen frequency and $\mathbf{x}$ the vector of associated clean displacement. Handled clean modes (λ, x) are with actual values. This kind of problems are activated by the keyword TYPE_RESU=' DYNAMIQUE' and a structure of data generates *Aster* of type mode_meca, mode_acou or mode_gene (according to the type of the data input).

- **The search for linear mode of buckling**. Within the framework of the linearized theory, while supposing *a priori* that the phenomena of stability are suitably described by the system of equations obtained by supposing the linear dependence of displacement compared to the level of critical load, the research of the mode of buckling x associated with this level of critical load $\mu = -\lambda$, brings back itself to a problem generalized to the eigenvalues of the form

$$\left(\mathbf{K} + \mu \mathbf{K}_g\right) x = 0 \Leftrightarrow \underbrace{\mathbf{K}}_{\mathbf{A}} \mathbf{x} = \lambda \underbrace{\mathbf{K}_g}_{\mathbf{B}} \mathbf{x}$$

  with $\mathbf{K}$ matrix of material rigidity and $\mathbf{K}_g$ geometrical matrix of rigidity. Handled clean modes (λ, x) are with actual values. This kind of problems are activated by the keyword TYPE_RESU=' MODE_FLAMB' and a structure of data generates *Aster* of type mode_flamb.

Caution:
- *In the code, one treats only the eigenvalues of the generalized problem, the variables λ. To obtain the true critical loads, the variables μ, they should be multiplied by -1.*
- *In GEP, to deal with problems with complex modes (nonsymmetrical matrices and/or with complex values), it is necessary to use MODE_ITER_SIMULT (METHODE=' SORENSEN'/'QZ').*

This operator allows also the study of **dynamic stability of a structure in the presence of depreciation and/or gyroscopic effects**. That led to the resolution of a modal problem of a nature higher, known as quadratic **(QEP)** [R5.01.02]. Complex values and clean vectors then are searched (l, x).

Code_Aster

Version default

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Date : 28/10/2014   Page : 7/19
Clé : U4.52.04   Révision   :
                    d2a45b254b1d

- The problem consists in finding $(\lambda, \mathbf{x}) \in (C, C^N)$ such as

$$\left(\lambda^2 \mathbf{B} + \lambda \mathbf{C} + \mathbf{A}\right) \mathbf{x} = \mathbf{0}$$

where typically, in linear mechanics, $\mathbf{A}$ will be the matrix of rigidity, $\mathbf{B}$ the matrix of mass and $\mathbf{C}$ the matrix of damping. Matrices $\mathbf{A}$, $\mathbf{B}$ and $\mathbf{C}$ are symmetrical and real matrices. complex eigenvalue λ is connected to the Eigen frequency f and with reduced damping ξ by $\lambda = \xi(2\pi f) \pm i(2\pi f)\sqrt{1-\xi^2}$. This kind of problems are activated by the keyword TYPE_RESU=' DYNAMIQUE' and a structure of data generates *Aster* of type mode_meca_c .

Caution:
- *In QEP, to deal with problems with nonsymmetrical matrices and/or complex values, it is necessary to use* MODE_ITER_SIMULT (METHODE=' SORENSEN'/'QZ').
- *Buckling (*TYPE_RESU=' MODE_FLAMB'*) is not licit in QEP.*
- *The test of Sturm is operative only in GEP with real symmetrical matrices. Apart from this framework (QEP, GEP with nonsymmetrical real matrices or matrix $\mathbf{A}$ complex symmetrical), the option '*BAND*'is proscribed and the post-checking based on Sturm N' is not activated (parameter '*VERI_MODE/STURM* inoperative).*

To solve these generalized or quadratic modal problems, *Code_Aster* propose various approaches. Beyond their digital specificities and functional calculuses which are taken again in the documents [R 5.01.01/02], one can synthesize them in the shape of the table below (**the values by default are materialized in fat**).

Operator Perimeter of application	Algorithm	Keyword	Advantages	Disadvantages
MODE_ITER_INV				*Only symmetrical reality (GEP and QEP).*
1 era phase (heuristics)				
Calculation of some modes	Bisection (without object in QEP).	'SEPARATED'		
Calculation of some modes	Secant Bissection+ (GEP) or Müller-Traub (QEP).	**'ADJUST'**	Better precision	Cost calculation
Improvement of some estimates	Initialization by the user	'NEAR'	Resumption of eigenvalues estimated by another process. Cost calculation of this phase quasi-no one	Pas de captures multiplicity
2 ième phase (method of the powers opposite)				*Only symmetrical reality (GEP and QEP)*
Basic method	Powers opposite	**'DIRECT'**	Very good construction of clean vectors	Not very robust
Option of acceleration	Quotient of	'RAYLEIGH'	Improve	Cost calculation

Code_Aster

Version default

Titre : *Opérateur MODE_ITER_INV*
Responsable : BRIE Nicolas

Date : 28/10/2014
Clé : U4.52.04

Page : 8/19
Révision :
d2a45b254b1d

Operator Perimeter of application	Algorithm	Keyword	Advantages	Disadvantages
	Rayleigh (without object in QEP)		convergence	
MODE_ITER_SIMULT				
Calculation of part of the spectrum	Bathe & Wilson	'JACOBI'		Not very robust *Only symmetrical reality (GEP)*
	Lanczos (Newman-Pipano in GEP and Jennings in QEP)	'TRI_DIAG'	Specific detection of the rigid modes.	*Only symmetrical reality (GEP and QEP)*
	IRAM (Sorensen)	**'SORENSEN'**	Increased robustness. Better complexities calculation and memory. Quality control of the modes.	Method by default. *Range in nonsymmetrical and with* **With** *complex symmetrical.*
Calculation of all the spectrum then filtering of a part.	QZ	**'QZ'**	Method of reference in term of robustness.	Very expensive in CPU and memory. To reserve for the small cases (<10^3 ddls). *Range in nonsymmetrical and with* **With** *complex symmetrical.*

Table 3.1-1. Summary of the modal methods of Code_Aster

When it is a question of determining some simple eigenvalues discriminated well or of refining some estimates, the operator MODE_ITER_INV (heuristics + power reverses), is often clearly shown. On the other hand, to capture a part significant of the spectrum, one has resorts to MODE_ITER_SIMULT, *via* methods of subspace (Lanczos, IRAM, Jacobi) or global method QZ (very robust but expensive method; to reserve for the small cases).

It is the second class of method which will interest us here.

For the methods of subspace, it consists in projecting the problem on a space whose size is higher than the number of desired eigenvalues but much lower than that of the problem. One arranges oneself so that this problem has a spectrum very close to that of the initial problem and that it takes a canonical form (tridiagonale, Hessenberg etc). Then one applies a total modal solvor (Jacobi for Bathe & Wilson, QR for Lanczos/IRAM) to this simplified problem. Finally one converts the modes obtained within the space of initial work.

As for global method QZ, it résoud directly and entirely the initial problem (GEP or linearized QEP) to improve the robustness of the process. It presents however the disadvantage of calculation all the spectrum. It is thus to hold for the small cases ($<10^3$ degrees of freedom).

It is completely recommended besides to benefit from the strong points of the two classes of method by refining the clean vectors obtained by MODE_ITER_SIMULT, *via*

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Version default

Date : 28/10/2014 Page : 9/19
Clé : U4.52.04   Révision : d2a45b254b1d

MODE_ITER_INV (OPTION=' PROCHE'). That will make it possible to reduce the standard of the final residue (cf §3.6.2).

Note:

> *One strongly advises a preliminary reading of the reference materials [R5.01.01] [R5.01.02]. It gives to the user the properties and the limitations, theoretical and practical, of the modal methods approached while connecting these considerations, which can sometimes appear a little ethereal, to a precise parameter setting of the options.*

3.2 Operands MATR_RIGI/MATR_A/MATR_MASS/MATR_RIGI_GEOM /MATR_B/MATR_AMOR/ MATR_C

The table below represents the operands to be used according standard to the keyword TYPE_RESU.

TYPE_RESU		
'DYNAMIC'	'MODE_FLAMB'	'GENERAL'
♦ MATR_RIGI = With	♦ MATR_RIGI = WITH	♦ MATR_A = WITH
♦ MATR_MASS = B	♦ MATR_RIGI_GEOM = B	♦ MATR_B = B
◊ MATR_AMOR = C	Without object	Except current perimeter

- ♦ MATR_RIGI or MATR_A=A
  Assembled matrix (symmetrical real) of type [matr_asse_*_R] GEP/QEP to be solved.

- ♦ MATR_MASS or MATR_RIGI_GEOM or MATR_B=B
  Assembled matrix (symmetrical real) of type [matr_asse_*_R] GEP/QEP to be solved.

- ◊ MATR_AMOR or MATR_C=C
  Assembled matrix (symmetrical real) of type [matr_asse_*_R] QEP to be solved.

3.3 Keyword TYPE_RESU

◊ TYPE_RESU=/ **'DYNAMIC'**   **[DEFECT]**
         /'MODE_FLAMB'
         /'GENERAL'

This keyword makes it possible to define the nature of the modal problem to treat: search for frequencies of vibration (classical case of dynamics with or without gyroscopic damping and effects) or search for critical loads (case of the theory of linear buckling, only in GEP) or research of eigenvalues and the modes associated with a matric system general.

According to this class of membership, the results are displayed and stored differently in the structure of data:

- • **In dynamics**, the frequencies are ordered by order ascending of the module of their variation to the shift (cf [R 5.01.01/02] §3,8/2.5). It is the value of the variable of access NUME_ORDRE structure of data. The other variable of access, NUME_MODE, is equal to the true modal position in the spectrum of the eigenvalue (determined by the test of Sturm cf §3.6 [R5.01.01]). This test of Sturm is licit only in GEP with real modes (real symmetrical matrices), in the other cases, GEP with complex modes and QEP, one poses NUME_MODE=NUMÉRIQUE_ORDRE.

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Version
default

Date : 28/10/2014 *Page : 10/19*
Clé : U4.52.04 *Révision :*
d2a45b254b1d

- **In buckling** and in the case general, the eigenvalues are stored by order ascending algebraic. Variables NUME_ORDRE and NUME_MODE take the same value equal to this order.

TYPE_RESU=' GENERAL' a problem of eigenvalues in the case of one makes it possible to solve **matric system general**. For the moment its perimeter is limited to GEPs standards (symmetrical real matrices). Its only difference with MODE_FLAMB is thus only in the denomination of the matrices: MATR_A/B rather than MATR_RIGI/MATR_RIGI_GEOM.

3.4 Keyword CALC_FREQ

♦ CALC_FREQ=_F (…
Keyword factor for the definition of the parameters of the first phase of calculation (localization of the eigenvalues).
Apart from the option 'NEAR', for the GEP, the localization of the eigenvalues S' generally carries out by a dichotomic separation of the frequencies (for the options 'ADJUSTS' and 'SEPARATE'), followed by a method of the secant (for the option: ' AJUSTE'). For the QEP, this localization is carried out by a method of Müller-Traub (for the option: 'AJUSTE').

3.4.1 Operand FREQ

◊ FREQ=lfreq
For a problem of search for eigenvalue of dynamic type ('DYNAMIC' TYPE_RESU=), this keyword corresponds to the list of the frequencies of which the use depends on OPTION chosen.
If OPTION='NEAR' is retained: it is the list of the frequencies whose one seeks the mode nearest. The list has at least 1 element and is ordered by ascending order.
If OPTION='SEPARATE' or 'ADJUSTS': they are the terminals of the intervals of research

$$FREQ= (F_1, F_2,…, F_{N-1}, F_N)$$

One will seek to separate the frequencies in the intervals

$$[F_1, F_2], [F_2, F_3]… [F_{N-2}, F_{N-1}], [F_{N-1}, F_N]$$

The list has at least two elements. The frequencies are positive. It is checked that the frequencies are given in the ascending order.

3.4.2 Operand AMOR_REDUIT

◊ AMOR_REDUIT=lamor
For QEP of the dynamic type (TYPE_RESU= 'DYNAMIQUE') and if the option NEAR was selected, one can initialize the method of the iterations opposite starting from a complex initial eigenvalue. To build this complex value, one uses the list of the arguments given under the keyword FREQ (list of frequencies) and AMOR_REDUIT (list of depreciation).
These two lists must have the same number of arguments.

3.4.3 Operand NMAX_FREQ

◊ NMAX_FREQ=nf   **0**   **[DEFECT]**
Maximum number of eigenvalues to calculate. This operand is ignored for the option 'NEAR'. For the other options, if the user does not inform this keyword, all the eigenvalues contained in the intervals specified by the user are calculated. If not, them NMAX_FREQ first eigenvalues, therefore lowest, are calculated

3.5 Keyword CALC_CHAR_CRIT

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Version default

Date : 28/10/2014 Page : 11/19
Clé : U4.52.04   Révision :
d2a45b254b1d

♦ CALC_CHAR_CRIT=_F (…
Keyword factor for the definition of the parameters of the first phase of calculation (localization of the critical loads).

Apart from the option 'NEAR', for the GEP, the localization of the eigenvalues S' generally carries out by a dichotomic separation of the critical loads (for the options 'ADJUSTS' and 'SEPARATE'), followed by a method of the secant (for the option: ' AJUSTE'). For the QEP, this localization is carried out by a method of Müller-Traub (for the option: 'AJUSTE').

3.5.1 Operand CHAR_CRIT

◊ CHAR_CRIT=lcharc
For a problem of search for eigenvalue of standard buckling of Euler (TYPE_RESU= 'MODE_FLAMB'), this keyword corresponds to the list of the critical loads of which the use depends onOPTION chosen.

If OPTION='PROCHE': it is the list of the critical loads whose one seeks the mode nearest. The list has at least 1 element.
If OPTION=' SEPARE' or 'ADJUSTS' : they are the terminals of the intervals of research
$$CHAR\_CRIT= (\lambda_{1,} \lambda_{2,} ..., \lambda_{n-1}, \lambda_n)$$

One will seek to separate the critical loads in the intervals
$$[\lambda_{1,} \lambda_2], [\lambda_{2,} \lambda_3] ... [\lambda_{n-2}, \lambda_{n-1}], [\lambda_{n-1}, \lambda_n]$$

The list has at least two elements. The critical loads are negative or positive. It is checked that the critical loads are given in the ascending order.

3.5.2 Operand NMAX_CHAR_CRIT

◊ NMAX_CHAR_CRIT=nf   **0**   **[DEFECT]**
Maximum number of critical loads to be calculated. This operand is ignored for the option 'NEAR'. For the other options, if the user does not inform this keyword, all the eigenvalues contained in the intervals specified by the user are calculated. If not, them NMAX_CHAR_CRIT first eigenvalues, therefore lowest, are calculated

3.6 Operands SEUIL_FREQ, SEUIL_CHAR_CRIT, PREC_SHIFT, NMAX_ITER_SHIFT

```
# IF TYPE_MODE=' DYNAMIQUE'
    ◊  PREC_SHIFT      =  PS     (0.05)        [DEFECT]
    ◊  SEUIL_FREQ      =  sf     (0.01)        [DEFECT]
    ◊  NMAX_ITER_SHIFT =  NS     (3)           [DEFECT]


# IF TYPE_MODE=' MODE_FLAMB' or 'GENERAL'
    ◊  PREC_SHIFT      =  PS     (0.05)        [DEFECT]
    ◊  SEUIL_CHAR_CRIT =  sf     (0.01)        [DEFECT]
    ◊  NMAX_ITER_SHIFT =  NS     (3)           [DEFECT]
```

The course of a modal calculation in this operator requires factorization LDL^T dynamic matrices $Q(\lambda)$ type (cf [R 5.01.01/02] §2.5/3.8)
$$Q(\lambda):=A - \lambda B \text{ (GEP)}$$
$$Q(\lambda):=\lambda^2 B + \lambda C + A \text{ (QEP)}$$
These factorization are dependent on digital instabilities when the shift λ is close to an eigenvalue of the problem. This detection takes place by comparing the loss of decimals of the diagonal terms of this factorized compared to their initial values (in absolute value). If the

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Version default

Date : 28/10/2014 Page : 12/19
Clé : U4.52.04 Révision :
d2a45b254b1d

maximum of this loss is higher than $ndeci$[1], the matrix is supposed to be singular and one each time seeks a shifted value of the shift (of $ps\%$) getting an invertible matrix. The operation is reiterated ns time (cf [R5.01.01] algorithm n°1). So at the end of these ns attempts, the shifted matrix is still not invertible, one transmits an information, an alarm or one stops in fatal error, according to the cases.

So during these shifts, the shift takes a value lower (in module) than sf, then the value is imposed to him $\lambda = -sf$. This parameter corresponds to a value threshold below which one considers that one has a numerically worthless value. This imposition thus makes it possible to distinguish these rigid modes moreover spectrum.

This value sf is also used to detect the quasi-worthless eigenvalues during the postprocessing of checking on the standard of the residue (cf [R 5.01.01/02] algorithm n°2/n°1).

Note:

At the time of the first passages, it is strongly advised not to modify these parameters which rather relate to the mysteries of the algorithm and which are initialized empirically with values standards.

3.7 Operand OPTION

◊ OPTION=
    'NEAR'
    One searches the mode to which the eigenvalue is closest to a given value. This value is indicated by:
- the argument lfreq keyword FREQ for GEP of a dynamic type (TYPE_RESU= 'DYNAMIQUE').
- the argument lcharc keyword CHAR_CRIT for a GEP of type linear buckling (TYPE_RESU= 'MODE_FLAMB').
- arguments lfreq and lamor keyword FREQ and AMOR_REDUIT for QEP of a dynamic type (TYPE_RESU= 'DYNAMIQUE').

There are as many searches for modes than of terms in this list (or these lists). If one wishes to calculate a multiple mode, this option should not be used because one mode will be found.

    'SEPARATE'
    One separates the eigenvalues by a method of bisection based on the criterion of Sturm. The terminals of the interval of research are:
- arguments of the list lfreq keyword FREQ for a generalized or quadratic problem of dynamic type (TYPE_RESU= 'DYNAMIQUE').
- arguments of the list lcharc keyword CHAR_CRIT for a generalized problem of standard linear buckling (TYPE_RESU= 'MODE_FLAMB').

    'ADJUSTS' **[DEFECT]**
After having separated the Eigen frequencies via the option 'SEPARATE' (in GEP only), one carries out additional iterations either by the method of secant (GEP) or by the method of Müller-Traub (QEP) to obtain a better precision on the eigenvalue.

3.7.1 Operands of the bisection (if OPTION= 'SEPARE' or 'ADJUSTS')

◊ NMAX_ITER_SEPARE=nis **(30)** **[DEFECT]**
◊ PREC_SEPARE =ps **(1.10⁻⁴)** **[DEFECT]**

Parameters of adjustment amongst iterations and the precision of separation for the dichotomizing search. These operands are ignored for the option 'NEAR' (Cf [R5.01.01] §4.2).

Note:

---

1 Fixed value *via* the parameter NPREC keyword SOLVEUR (by default $ndeci=8$).

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Version default

Date : 28/10/2014 Page : 13/19
Clé : U4.52.04 Révision :
d2a45b254b1d

At the time as of first passages, it is strongly advised not to modify these parameters which rather relate to the mysteries of the algorithm and which are initialized empirically with values standards.

3.7.2 Operands of the secant (if OPTION= 'AJUSTE')

◊   NMAX_ITER_AJUSTE = denied   **(15)**   **[DEFECT]**
◊   PREC_AJUSTE   = Pa   **(1.10⁻⁴)**   **[DEFECT]**
Parameters of adjustment amongst iterations and the precision of separation for the method of the secant. These operands are used only for the option 'ADJUSTS' (Cf [R5.01.01] §4.2).

Note:

At the time as of first passages, it is strongly advised not to modify these parameters which rather relate to the mysteries of the algorithm and which are initialized empirically with values standards.

3.8   Keyword factor CALC_MODE

◊   CALC_MODE=_F (...
Keyword factor for the definition of the parameters of calculation of the second phase of calculation (method of the powers opposite).

3.8.1 Operand OPTION

◊   OPTION=
Definition of the method of the powers opposite (confer [R 5.01.01/02] §4.3/3.3):

'DIRECT'   standard method in GEP or alternative of Jennings in QEP.
[DEFECT]
'RAYLEIGH'   Acceleration via the quotient of Rayleigh (only in GEP)

3.8.2 Operand NMAX_ITER

◊   NMAX_ITER=nim   **(30)**   **[DEFECT]**
Maximum number of iterations of the method of the powers opposite for the research of the clean modes.

3.8.3 Operand PREC

◊   PREC=pm   **(1.10⁻⁵)**   **[DEFECT]**
Test of stop of the method of the powers opposite.

3.9   Keyword factor SOLVEUR

◊   SOLVEUR=_F(),

One has access to all the parameters of the direct linear solveurs (METHODE=' LDLT'/'MULT_FRONT'/'MUMPS').

In parallel mode, one advises the parameter setting particularly ² METHODE=' MUMPS' and RENUM=' QAMD' .

---

2   In order to at least reduce the cost in time of the phase of analysis (sequential) of MUMPS. This parameter setting is done however to the detriment of consumption memory. But this overcost quickly proves compensated by the distribution of the data on the processors which parallelism implies.

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Version default

Date : 28/10/2014 Page : 14/19
Clé : U4.52.04
Révision :
d2a45b254b1d

For more details on the solveurs, one will be able to consult the document [U4.50.01]. Concerning parallelism, one returns to the document [U2.08.06] and the dedicated paragraph of the document [U2.06. 01].

3.10 Keyword factor `VERI_MODE`

◊ VERI_MODE=_F (…
Keyword factor for the definition of postprocessings of checking of the clean modes. These postprocessings relate to only the standard of the residue of the modes (cf [R5.01.01] §3.7.4 and [R5.01.02] §2.5.4).

Note:
- *At the time of the first passages, it is strongly advised not to modify these parameters which rather relate to the mysteries of the algorithm and which are initialized empirically with values standards.*
- *Contrary to its alter-ego, MODE_ITER_SIMULT, this keyword factor does not comprise a keyword of the type STURM and PREC_SHIFT. The phase of postprocessing and checking does not comprise indeed a test of Sturm which would be redundant with the first part heuristics. Methods of type "power" being less robust than those of standard "subspace", the value by default of the threshold R is less demanding (10^{-2} instead of 10^{-6}).*

3.10.1 Operand `STOP_ERREUR`

◊ STOP_ERREUR=/**'YES'** **[DEFECT]**
/'NOT'
Allows to indicate to the operator if it must stop ('YES') or to continue ('NOT') if one of the criteria THRESHOLD or STURM (only with MODE_ITER_SIMULT) is not checked.
By default the concept of exit is not produced.

3.10.2 Operand `THRESHOLD`

◊ SEUIL=r **(1.10⁻²)** **[DEFECT]**
Tolerance level for the standard of error relative of the mode to the top of which he is regarded as forgery or too approximated (cf [R 5.01.01/02] algorithm n°2/n°1).

3.11 Operand `INFORMATION`

◊ INFO=/**1** **[DEFECT]**
/2
Indicate the level of impression in the file MESSAGE (.mess).

1 Impression on the file 'MESSAGE'eigenvalues, of their modal position, L' reduced damping, standard of error *a posteriori* and certain useful parameters to follow the course of calculation.
2 Impression more provided rather reserved to the developers.

3.12 Operand `TITLE`

◊ TITRE=ti
Title attached to the concept produced by this operator [U4.03.01].

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Version
default

Date : 28/10/2014 Page : 15/19
Clé : U4.52.04   Révision :
                    d2a45b254b1d

4   Production run

4.1   Checking

Matrices $\mathbf{A}$, $\mathbf{B}$ and $\mathbf{C}$, arguments of the keywords (MATR_A/MATR_RIGI), (MATR_MASS/MATR_RIGI_GEOM/MATR_B) and (MATR_AMOR/MATR_C), must be coherent between them (i.e. to be based on the same classification and the same mode of storage). The operator checks that for the options 'SEPARATE' and 'ADJUSTS', the list of the values of the arguments of the keyword FREQ or CHAR_CRIT has, at least, two terms.

It checks also a certain coherence of the parameters of the various algorithms.

4.2   Execution

For the option 'ADJUSTS', if the separation is not possible and that in a given interval there is more than one value of eigenvalue, one does not apply the method of adjustment with this interval. On the other hand, one will carry out during the calculation of the modes of the réorthogonalisations compared to the preceding modes contained in the interval (this makes it possible to calculate modes associated with a multiple eigenvalue).

For the option 'SEPARATE', having obtained an interval determining an eigenvalue, one takes for the calculation of the mode the medium of the interval. During the calculation of the mode, the value of the eigenvalue is still refined. It is the result of the opposite iteration itself.

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Version default

Date : 28/10/2014 Page : 16/19
Clé : U4.52.04   Révision :
d2a45b254b1d

5   Modal parameters Normalizes modal Position modes

At exit of this operator, the real or complex clean modes are standardized with largest components which is not a multiplier of Lagrange. To choose another standard, the order should be used NORM_MODE [U4.52.11].

In the case of a dynamic calculation, the structure of data mode_meca_*, contains, besides the frequencies of vibration and of the associated modal deformations, of the modal parameters (generalized mass, generalized stiffness, factor of participation, effective mass). One will find the definition of these parameters in [R5.01.03].
In the case of a linear calculation of buckling, the structure of data mode_flamb, contains only the critical loads and the associated deformations.

In the case of a dynamic calculation with real modes (real symmetrical matrices), the modal position of the modes corresponds to the position of the mode in the whole of the spectrum defined by the matrices and $\mathbf{A}$ and $\mathbf{B}$.
In the case of a linear calculation of buckling, the modal positions of the critical loads are allotted of 1 to nf (nf being the number of critical loads calculated) by classifying the critical loads by order ascending in absolute value. All the modal positions are thus positive.

For the option NEAR, the modal positions are allotted of 1 to nf (nf being the number of calculated eigenvalues), by taking the eigenvalues in the order of the list indicated under FREQ or CHAR_CRIT.

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Version default

Date : 28/10/2014 Page : 17/19
Clé : U4.52.04 Révision :
d2a45b254b1d

6   Impression of the results

To display the modal parameters associated with each mode and the coordinates with the modes, the operator should be used IMPR_RESU[U4.91.01] in the following way:

- Posting of the modal parameters only in the form of table:

```
IMPR_RESU (   RESU=_F ( RESULTAT=mode,
                        TOUT_PARA=    'YES',
                        TOUT_CHAM= 'NON'));
```

- Posting of the modal parameters and the clean vectors:

```
IMPR_RESU (   RESU=_F (RESULTAT=mode,
                       TOUT_PARA= 'OUI',
                       TOUT_CHAM= 'OUI'));
```

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Version
default

Date : 28/10/2014 Page : 18/19
Clé : U4.52.04   Révision   :
*   d2a45b254b1d*

7   Examples

Are `mass` and `rigidity` two matrices assembled beforehand by the operator `ASSE_MATRICE` starting from elementary matrices of mass (OPTION= 'MASS_MECA') and of rigidity (OPTION= 'RIGI_MECA').

One calculates the modes of Eigen frequency understood in the band $50\mathrm{Hz}$ with $150\mathrm{Hz}$ with the operator `MODE_ITER_INV` as follows:

```
mode=MODE_ITER_INV
            (   MATR_RIGI=rigidite,
                MATR_MASS=masse,
                CALC_FREQ=_F (OPTION=' AJUSTE',
                FREQ= (50. , 150.))
            )
```

One calculates the modes of Eigen frequency closest to the frequencies 20Hz and 50Hz with the operator `MODE_ITER_INV` as follows:

```
mode=MODE_ITER_INV
            (   MATR_RIGI=rigidite,
                MATR_MASS=masse,
                CALC_FREQ=_F (   OPTION=' PROCHE',
                FREQ= (50. , 150.)),
                CALC_MODE=_F (OPTION=' RAYLEIGH')
            )
```

The acceleration of convergence by using the coefficient of Rayleigh was selected.

Code_Aster

Titre : Opérateur MODE_ITER_INV
Responsable : BRIE Nicolas

Version default

Date : 28/10/2014 Page : 19/19
Clé : U4.52.04   Révision :
d2a45b254b1d

8   Remarks of use

The cost of this operator can be high because:
- each dichotomy requires a factorization (if OPTION=' SEPARE'),
- each iteration of secant or Müller-Traub (if OPTION=' AJUSTE') require also a factorization.

It can be more judicious to make:
- a search for eigenvalues by the operator MODE_ITER_SIMULT [U4.52.03],
- then to refine the results got by MODE_ITER_INV by using the option 'NEAR' of CALC_FREQ or CALC_CHAR_CRIT and the option 'RAYLEIGH' of CALC_MODE to improve the clean vectors.