

Operator MODE_ITER_SIMULT

1 Drank

That that is to study vibrations of a structure (possibly damped or revolving) or to search its buckling modes, the mechanic must often solve a modal problem: either **generalized (GEP)** [R5.01.01], or **quadratic (QEP)** [R5.01.02]. With this intention, *Code_Aster* proposes two operators (and their macros): `MODE_ITER_SIMULT` and `MODE_ITER_INV` [U4.52.04].

The first, which occupies us in this note, **is rather to use when one seeks a significant part of the spectrum** (methods of subspace or global method). Second is to be privileged when one is interested in only some eigen modes (typically a half-dozen) or when one wishes to refine some estimates (possibly coming from `MODE_ITER_SIMULT`).

`MODE_ITER_SIMULT` determines a set of **eigen modes**, either by a method of type subspace (Bathe & Wilson, Lanczos or Sorensen) or by a total method of type QR (QZ for the small problems). Its four methods are accessible to treat a **standard GEP** (symmetric reality): classical dynamic computation (without damping and gyroscopic effect) or problem of buckling of Eulerian.

Besides to treat this kind of GEP effectively, one proposes to proceed in several stages:

- **To gauge** the zones of interest by a `INFO_MODE` [U4.52.01] initial on a list of frequencies (resp. critical loads) given,
- To look at the numbers of associated eigen modes,
- **To start again** one or more computations `MODE_ITER_SIMULT+OPTION=' BANDE'` while trying to **balance the sub-bands and by re-using** the `sd_table` generated by `INFO_MODE`. To optimize performances CPU, it is also possible to parallel computations on the sub-bands thanks to operator `MACRO_MODE_MECA` [U4.52.02] in parallel, which can get a gain of a factor 10 to 20 over the computing time, and several tens of for hundred on the peak of memory.

On the other hand, as soon as one treats a QEP or an atypical GEP (complex and/or asymmetric matrix), the spectrum becomes complex. Sequence `INFO_MODE+MODE_ITER_SIMULT` is not then possible any more. Certain key words or values become without object (`OPTION=' BANDE'`, `VERI_MODE/STURM...`) and only the methods Sorensen, Lanczos or QZ remain available.

This operator produces a concept `mode_meca_*` (case dynamic) or `mode_flamb` (case buckling of Eulerian, only in QEP) according to the value indicated in key word `TYPE_RESU`.

In a first approach one can be satisfied to inform the parameters: `MATR_*` , `TYPE_RESU`, `CALC_*/OPTION` and `FREQ` (or `CHAR_CRIT`).

In certain cases, it can be more interesting to use macro-commands `MACRO_MODE_MECA` [U4.52.02] or `CALC_MODAL` [U4.52.10].

Contents

1	But1.....	
2	Syntaxe5.....	
3	Opérandes11.....	
3.1	Principles	11.3.2
	Operands MATR_RIGI/MATR_A/MATR_MASS/MATR_RIGI_GEOM /MATR_B/MATR_AMOR/MATR_C14.....	
3.3	Key word TYPE_RESU14.....	
3.4	Key word METHODE15.....	
3.4.1	Operands of IRAM (if METHODE= `SORENSEN').....	16
3.4.2	Operands of the method of Lanczos (if METHODE= `TRI_DIAG').....	16
3.4.3	Operands of the method of Bathe & Wilson (if METHODE= `JACOBI').....	16
3.4.4	Operands of the method QZ (if METHODE= `QZ').....	17
3.5	Key word CALC_FREQ17.....	
3.5.1	Operand FREQ17.....	
3.5.2	Operand AMOR_REDUIT18.....	
3.5.3	Operand NMAX_FREQ18.....	
3.6	Key word CALC_CHAR_CRIT18.....	
3.6.1	Operand CHAR_CRIT19.....	
3.6.2	Operand NMAX_CHAR_CRIT19.....	
3.7	Operand APPROCHE20.....	
3.8	Operand OPTION20.....	
3.9	Operands SEUIL_FREQ/CHAR_CRIT, PREC_SHIFT, NMAX_ITER_SHIFT21.....	
3.10	Operand DIM_SOUS_ESPACE22.....	
3.11	Key word VERI_MODE23.....	
3.11.1	Operand STOP_ERREUR23.....	
3.11.2	Operand SEUIL23.....	
3.11.3	Operand STURM23.....	
3.11.4	Operand PREC_SHIFT23.....	
3.12	Operand STOP_BANDE_VIDE23.....	
3.13	Operand INFO24.....	
3.14	Operand TITRE24.....	
4	Phase of vérification25.....	
5	Phase of exécution26.....	
5.1	Vérification26.....	
5.2	Actions by défaut26.....	
6	Parameters modal Normalizes modes Position modale27.....	
7	Optimization of performances CPU27.....	
7.1	Parallelism of the solver linéaire27.....	
7.2	Computation of the modes by.....	under-bandes27

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

8 Printing of results	28
9 Sort of Characterization modes of mode_meca_*29.....	
10 Exemples30.....	
10.1 Computation of the 5 eigen modes closest to a given frequency ().....	30
10.2 Computation of the critical loads contained in a bande30.....	
10.3 Sequence INFO_MODE+MODE_ITER_SIMULT (extracted from SDLS504a).....	30

2 Syntax

```
mode_ [*] =MODE_ITER_SIMULT
```

Standard of problem

```
◇TYPE_RESU=/ "DYNAMIQUE" [DEFAULT]
              /"MODE_FLAMB"
              /"GENERAL"
```

```
# If TYPE_RESU=
`DYNAMIQUE'
```

Characteristic of computation

```
(
  ◆MATR_RIGI=A/ [matr_asse_DEPL_R]
                  /[matr_asse_DEPL_C]
                  /[matr_asse_PRES_R]
                  /[matr_asse_GENE_R]
                  /[matr_asse_GENE_C]
  ◆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]
                  /[matr_asse_GENE_R]

  ◇CALC_FREQ=_F ( ◇OPTION=/ "CENTER"
                  /"TAPE"
                  /"PLUS_PETITE" [DEFAULT]
                  /"PLUS_GRADE"
                  /"TOUT" (only with QZ)

  # If OPTION= `PLUS_PETITE'
  ◇NMAX_FREQ=/10
[DEFAULT] /nf [I]

  # If OPTION= `PLUS_GRADE'
  ◇NMAX_FREQ=/1 [DEFAULT]
/nf [I]

  # If OPTION= `CENTER'
  ◆ FREQ=1_f [1_R]
  ◇ AMOR_REDUIT=1_a [1_R]
  ◇NMAX_FREQ=/10
[DEFAULT] /nf [I]

  # If OPTION= `BANDE'
  ◆ FREQ=1_f [1_R]
  ◇ TABLE_FREQ=table_ftable_sdaster ]

)
```

Parameter suitable for the QEP

```
◇ APPROCHE=/ "REEL" [DEFAULT]
              /"IMAG"
              /"COMPLEXE" (only Sorensen)
```

Characteristic of the space of projection

```
◇DIM_SOUS_ESPACE=des [I]
◇COEF_DIM_ESPACE=mse [I]
EXCLUDED ("DIM_SOUS_ESPACE", "COEF_DIM_ESPACE")
```

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

For pre and postprocessings

◇	<code>PREC_SHIFT=/0.05</code>	[DEFAULT]
	<code> /p_shift</code>	[R]
◇	<code>NMAX_ITER_SHIFT=/3</code>	[DEFAULT]
	<code> /n_shift</code>	[I]
◇	<code>SEUIL_FREQ=/1.E-2</code>	[DEFAULT]
	<code> /f_seuil</code>	[R]

```
# If TYPE_RESU= 'MODE_FLAMB'
```

Characteristic of computation

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

```
    ◇CALC_CHAR_CRIT =_F ( ◇OPTION=/ "CENTER"
                          /"TAPE"
                          /"PLUS_PETITE" [DEFAULT]
```

```
    # If OPTION=
    'PLUS_PETITE'
```

```
    ◇NMAX_CHAR_CRIT=/10
[DEFAULT]
```

```
    /nf [I]
```

```
    # If OPTION= 'CENTER'
```

```
    ◆CHAR_CRIT= l_c [l_R]
    ◇NMAX_CHAR_CRIT=/10
```

```
[DEFAULT]
```

```
    /nf [I]
```

```
    # If OPTION= 'BANDE'
```

```
    ◆CHAR_CRIT=l_c [l_R]
    ◇TABLE_CHAR_CRIT=table_c [table_sdaster]
    )
```

Parameter suitable for QEP

```
    ◇APPROCHE=/ "REEL" [DEFAULT]
                /"IMAG"
```

Characteristic of the space of projection

```
    ◇DIM_SOUS_ESPACE=des [I]
    ◇COEF_DIM_ESPACE=mse [I]
    EXCLUDED ("DIM_SOUS_ESPACE", "COEF_DIM_ESPACE")
```

For pre and postprocessings

```
    ◇PREC_SHIFT=/0.05
[DEFAULT]
```

```
    /p_shift [R]
```

```
    ◇NMAX_ITER_SHIFT=/3 [DEFAULT]
```

```
    /n_shift [I]
```

```
    ◇SEUIL_CHAR_CRIT=/1.E-2 [DEFAULT]
```

```
    /c_seuil [R]
```

```
# If TYPE_RESU= `GENERAL'
```

Characteristic of computation

```
(
    ◆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=/ "CENTER"
                                /"TAPE"
                                /"PLUS_PETITE" [DEFAULT]
                                /"TOUT" (only with QZ)

    # If OPTION= `PLUS_PETITE'
        ◇NMAX_CHAR_CRIT=/10
[DEFAULT]
                                /nf
                                [I]
    # If OPTION= `CENTER'
        ◆CHAR_CRIT=1_c
                                [1_R]
        ◇NMAX_CHAR_CRIT=/10
[DEFAULT]
                                /nf
                                [I]

    #Si OPTION= `BANDE' (only GEP with real symmetric matrixes)
        ◆CHAR_CRIT=1_c
                                [1_R]
        ◇TABLE_CHAR_CRIT=table_c
                                [table_sdaster]
        )

# Characteristic of the space of projection
    ◇DIM_SOUS_ESPACE=des
                                [I]
    ◇COEF_DIM_ESPACE=mse
                                [I]
    EXCLUDED ("DIM_SOUS_ESPACE", "COEF_DIM_ESPACE")

# For pre and postprocessings
    ◇ PREC_SHIFT=/0.05
                                [DEFAULT]
                                /p_shift
                                [R]
    ◇ NMAX_ITER_SHIFT=/3
                                [DEFAULT]
                                /n_shift
                                [I]
    ◇ SEUIL_CHAR_CRIT=/1.E-2
                                [DEFAULT]
                                /c_seuil
                                [R]
```

Choice from the method

```

◇ METHODE=/ "SORENSEN" [DEFAULT]
/"TRI_DIAG" (only real symmetric GEP/QEP)
/"JACOBI" (except in QEP)
/"QZ" (problem of small sizes <math>10^3</math> degrees of freedom)
    
```

Parameter setting internal of methods

```
# If METHODE= `SORENSEN'
```

```

◇ PREC_SOREN=/0 [DEFAULT]
/pso [R]
◇ NMAX_ITER_SOREN= /20 [DEFAULT]
/nso [I]
◇ PARA_ORTHO_SOREN=/0.717 [DEFAULT]
/porso [I]
    
```

```
# If METHODE= `TRI_DIAG'
```

```

◇ PREC_ORTHO=/1.E-12 [DEFAULT]
/po [R]
◇ NMAX_ITER_ORTHO=/5 [DEFAULT]
/nio [I]
◇ PREC_LANCZOS=/1.E-8 [DEFAULT]
/pl [R]
◇ NMAX_ITER_QR=/30 [DEFAULT]
/nim [I]
◇ OPTION=/ "SANS" [DEFAULT]
/"MODE_RIGIDE"
    
```

```
# If METHODE= `JACOBI'
```

```

◇ PREC_BATHE=/1.E-10 [DEFAULT]
/pbat [R]
◇ NMAX_ITER_BATHE=/40 [DEFAULT]
/nbat [I]
◇ PREC_JACOBI=/1.E-2 [DEFAULT]
/pjaco [R]
◇ NMAX_ITER_JACOBI=/12 [DEFAULT]
/njaco [I]
    
```

```
# If METHODE= `QZ'
```

```

◇ TYPE_QZ=/ "QZ_SIMPLE" [DEFAULT]
/"QZ_EQUI"
/"QZ_QR" (if GEP with matrixes SPD)
    
```

For final checks

```

◇ VERI_MODE= _F (
◇ STOP_ERREUR=/ "OUI" [DEFAULT]
/"NON"
◇ SEUIL=/1.E-6
)
[DEFAULT]
/r [R]
◇ PREC_SHIFT=/0.05 [DEFAULT]
/prs [R]
◇ STURM="/OUI" [DEFAULT]
/"NON"
)
    
```

Various

```

◇ STOP_BANDE_VIDE="/OUI" [DEFAULT]
    
```

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

/"NON"

◇SOLVEUR=_F (For more details to see it document [U4.50.01])

◇INFO=/1 [DEFAULT]
/2 [I]

◇TITER=ti

);

Results of the modal problem

```
SiMATR_AMOR or MATR_C= [matr_asse_DEPL_R] then [*] - >mode_meca_c
  SiTYPE_RESU= ` MODE_FLAMB'alors [*] - >mode_flamb
  SiTYPE_RESU= ` GENERAL'alors [*] - >mode_flamb
SiMATR_RIGI or MATR_A= [matr_asse_DEPL_C] then [*] - >meca_c
SiMATR_RIGI or MATR_A= [matr_asse_DEPL_R] then [*] - >mode_meca
SiMATR_RIGI or MATR_A= [matr_asse_PRES_R] then [*] - >mode_acou
SiMATR_RIGI or MATR_A= [matr_asse_GENE_R] then [*] - >mode_gene
SiMATR_RIGI or MATR_A= [matr_asse_GENE_C] then [*] - >mode_gene
```

3 Operands

3.1 Principles

This operator solves **the problem generalized (GEP)** with the eigenvalues according to [R5.01.01]: To find (λ, \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, symmetric matrixes or not. To model a hysteretic damping in the study of free vibrations of a structure, the matrix \mathbf{A} can be complex symmetric [U2.06.03] [R5.05.04].

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

- **The study of free vibrations of an undamped** and nonrevolving structure. 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 material, noted, \mathbf{K} symmetric stiffness matrix real (possibly increased geometrical stiffness matrix noted \mathbf{K}_g , if the structure is prestressed), and \mathbf{B} is the mass matrix or of noted inertia \mathbf{M} (symmetric real). The eigenvalues obtained are the squares of the pulsations associated with the sought frequencies. The system to be solved can be written

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

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

- **The search for linear mode of buckling**. In the frame 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 search of the mode of buckling \mathbf{X} associate on this level of critical load $\mu = -\lambda$, is brought back to a problem generalized to the eigenvalues of the form

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

with \mathbf{K} material stiffness matrix and \mathbf{K}_g geometrical stiffness matrix. The handled eigen modes (λ, \mathbf{x}) are with actual values. This kind of problems are activated by the key word `TYPE_RESU=' MODE_FLAMB'` and generate a data structure *Aster* of the mode_flamb type.

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, for dealing with problems with complex modes (asymmetric matrixes and/or with complex values), it is necessary to use `MODE_ITER_SIMULT (METHODE=' SORENSEN'/'QZ')`.

This operator allows also the study of **the 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 eigenvectors then are searched (λ, \mathbf{x}) .

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

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

where typically, in linear mechanics, **A** will be the stiffness matrix, **B** the mass matrix and **C** the damping matrix. The matrixes **A**, **B** and **C** are symmetric and real matrixes. The complex eigenvalue λ is connected to the eigenfrequency f and with reduced damping ξ par. $\lambda = \xi(2\pi f) \pm i(2\pi f)\sqrt{1-\xi^2}$. This kind of problems are activated by the key word `TYPE_RESU=' DYNAMIQUE'` and generate a data structure *Aster* of the `mode_meca_c` type.

Caution:

- In QEP, for dealing with problems with asymmetric matrixes 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 type is operative only in GEP with real symmetric matrixes. Outside this frame (QEP, GEP with asymmetric real matrixes or symmetric **A** complex matrix), the option "TAPE" is proscribed and the post-checking based on Sturm type is not activated (inoperative parameter " VERI_MODE/STURM).

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

Operator Perimeter D" application	Algorithm	Key word	Advantages	Disadvantages
MODE_ITER_INV				Only symmetric reality (GEP and QEP).
<i>1st phase (heuristic)</i>				
Computation of some Bisection	modes (without object in QEP).	"SEPARATE"		
Computation of some modes	Bisection+ Secant (GEP) or Müller-Traub (QEP).	"ADJUSTS"	Better accuracy	Cost computation
Improvement of some Initialization	estimates by the user	"NEAR"	Taken again eigenvalues estimated by another process. Cost computation of this phase almost zero	No capture of multiplicity
<i>2nd phase (method of the powers opposite)</i>				Only symmetric reality (GEP and QEP)
basic Method	Powers opposite	"DIRECT"	Very good construction of eigenvectors	Not very robust
Option of acceleration	Quotient of Rayleigh (without object in QEP)	"RAYLEIGH"	Improves convergence	Cost computation
MODE_ITER_SIMULT				
Computation of part of the spectrum	Bathe & Not very	<i>robust</i> Wilson "		JACOBI" Only symmetric

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

Operator Perimeter D” application	Algorithm	Key word	Advantages	Disadvantages
				<i>reality (GEP)</i>
	Lanczos (Newman-Pipano in GEP and Jennings in QEP)	“TRI_DIAG”	Detection specific of the rigid modes.	<i>Only symmetric reality (GEP and QEP)</i>
	IRAM (Sorensen)	“SORENSEN”	increased Robustness. Better complexities computation and memory. Quality control of the modes.	Method by default. <i>Range into asymmetric and with A symmetric complex.</i>
Computation of all the spectrum then filtering of a part.	QZ	“QZ”	Method of reference in term of robustness.	Very expensive in CPU and memory. A to reserve for the small cases (<103 degrees of freedom). <i>Range into asymmetric and with A symmetric complex.</i>

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

When it is a question of determining **some well discriminated simple eigenvalues** or of refining some estimates, operator MODE_ITER_INV (heuristic + 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 the methods of subspace (Lanczos, IRAM, Jacobi) or the total 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 (tridiagonal, Hessenberg etc). Then one applies a total modal solver (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 the total 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 computation 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 eigenvectors obtained by MODE_ITER_SIMULT, via MODE_ITER_INV (OPTION=' PROCHE '). That will make it possible to reduce the norm of the final residue (cf §3.6.2).

In addition, to treat a standard GEP more effectively, one proposes to proceed in several stages:

- **To gauge** the zones of interest by an initial call to `INFO_MODE` on a list of frequencies ¹ (resp. critical loads) given,
- **To look at** the numbers of eigen modes displayed in the message file (or the generated `sd_table`),
- **To start again** one or more computations `MODE_ITER_SIMULT+OPTION=' BANDE '` (or `MACRO_MODE_MECA`) while trying to **balance** the tapes.

To save time, one can even pool (and it is strongly advised!) part of the cost computation of the initial `INFO_MODE` by notifying in `MODE_ITER_SIMULTs` the name generated `sd_table` (cf key words `TABLE_`). This sequence can thus return the overcost of negligible `INFO_MODE` and effectively guide modal computation.

On the other hand, as soon as one treats a QEP or an atypical GEP (complex and/or asymmetric matrix), the spectrum becomes complex. Sequence `INFO_MODE+MODE_ITER_SIMULT` is not then possible any more. Certain key words or values become without object (`OPTION=' BANDE ', VERI_MODE/STURM...`) and only the methods Sorensen, Lanczos or QZ remain available.

Note:

- One strongly advises a preliminary reading of documentations of reference [R5.01.01] [R5.01.02] [R5.01.04]. It gives and to the user the properties 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 key word `TYPE_RESU`.

TYPE_RESU		
"DYNAMIQUE"	"MODE_FLAMB"	"GENERAL"
◆ <code>MATR_RIGI = A</code>	◆ <code>MATR_RIGI = A</code>	◆ <code>MATR_A = A</code>
◆ <code>MATR_MASS = B</code>	◆ <code>MATR_RIGI_GEOM = B</code>	◆ <code>MATR_B = B</code>
◇ <code>MATR_AMOR = C</code>	Without object	Except current perimeter

◆`MATR_RIGI/MATR_A=A`

Stamps assembled, real (symmetric or not) or complex symmetric, of type `[matr_asse*_R/C]` of the GEP/QEP to be solved.

◆`MATR_MASS/MATR_RIGI_GEOM/MATR_B=B`

Stamps assembled, real (symmetric or not), of type `[matr_asse*_R]` of the GEP/QEP to be solved.

◇`MATR_AMOR/MATR_C=C`

Stamps assembled, real (symmetric or not), of type `[matr_asse*_R]` of the QEP to be solved.

Note:

- If the matrix `A` is complex symmetric or if one of matrixes `A/B` or `C` is asymmetric real, only the methods of Sorensen and QZ are licit. One cannot then use the computation option "`BANDAGES`" and, for the case or the matrix `A` is complex, a frequential limit null ("`OPTION=PLUS_PETITE`" or "`CENTER`" with $f=0$).

3.3 Key word `TYPE_RESU`

¹ of the reasons of costs computation, it is to better limit the list to a dozen values, to the maximum.

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

```
◇TYPE_RESU=/ "DYNAMIQUE" [DEFAULT]
              /"MODE_FLAMB"
              /"GENERAL"
```

This key word makes it possible to define the nature of the modal problem in treating: 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). According to this class of membership, the results are displayed and stored differently in data structure:

- **In dynamics** (TYPE_RESU=' DYNAMIQUE'), the frequencies are ordered by order ascending of the modulus 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 of data structure. 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 type cf §3.6 [R5.01.01]). This test of Sturm type is licit only in GEP with real modes (real symmetric matrixes), in the other cases, GEP with complex modes and QEP, one poses NUME_MODE=NUMÉRIQUE_ORDRE.
- **In buckling** (TYPE_RESU=' MODE_FLAMB' or TYPE_RESU=' 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' makes it possible to solve value problems in the case of clean a **general matric system**. For time its perimeter is restricted in GEPs standards (symmetric real matrixes). Its only difference with MODE_FLAMB is thus only in the denomination of the matrixes: MATR_A/B rather than MATR_RIGI/MATR_RIGI_GEOM.

3.4 Key word METHODE

Four methods of resolution are available to solve the problem with the eigenvalues (cf table 3.1.1):

```
◇ METHODE="/"SORENSEN" [DEFAULT]
```

One uses the method of Sorensen (external package ARPACK) to compute: the eigen modes of the GEP or the QEP (cf [R 5.01.01/02] §7/4). Its perimeter includes the real, symmetric matrixes or not, even a matrix A complex symmetric.

```
◇ /"TRI_DIAG"
```

One uses the method of Lanczos to compute: (alternative of Newmann-pipano in GEP, Parlett & Saad in QEP) the eigen modes of the GEP or the QEP (cf [R 5.01.01/02] §6/4). Its perimeter is restricted with the real symmetric matrixes.

```
◇OPTION=/ "MODE_RIGIDE"
           /"SANS" [DEFAULT]
```

Key word usable only with the method of Lanczos for a GEP. It makes it possible to detect and calculate as a preliminary, by an algebraic method the modes of body of rigid. They are used thereafter to compute: the other modes with the algorithm of Lanczos. They are provided to the user only if they belong to the modes requested. If the modes of rigid body are calculated without using this option, the eigenvalues calculated by the algorithm of Lanczos are not null but very close to zero.

```
◇ /"JACOBI"
```

One uses the method of Bathe & Wilson (then method of Jacobi on the system project) to compute: the eigen modes of the GEP (cf [R5.01.01] §8). Its perimeter is restricted with the real symmetric matrixes.

```
◇/ "QZ"
```

One uses the method QZ of external library LAPACK to compute: the eigen modes of the GEP or the QEP (cf [R 5.01.01/02] §9/5). Its perimeter includes the real, symmetric matrixes or not, even a matrix A complex symmetric. This method of very expensive reference is to be held for the problems smalls (<103 degrees of freedom).

3.4.1 Operands of IRAM (if `METHODE= `SORENSEN``)

◇ `PREC_SOREN=ps0` (0.) [DEFAULT]

Note:

- *The method considers whereas it must work with the smallest possible accuracy, the “zero machine”. To have an order of magnitude of it, in double precision on the machines standards, this value is close to 2.22 . 10⁻¹⁶.*

◇ `NMAX_ITER_SOREN=nso` (20) [DEFAULT]
◇ `PARA_ORTHO_SOREN=porso` (0.717) [DEFAULT]

They are parameters of adjustment of the necessary accuracy on the modes (by default, the machine accuracy is selected), amongst restartings authorized of the method of Sorensen (cf [R5.01.01] §7) and of the coefficient of orthogonalization of the IGSM of Kahan-Parlett (cf [R5.01.01] appendix 2).

Note:

- *During the first transitions, it is strongly advised not to modify these advanced parameters of the algorithm and which are initialized empirically with values standards.*

3.4.2 Operands of the method of Lanczos (if `METHODE= `TRI_DIAG``)

◇ `PREC_ORTHO=po` (1.10⁻¹²) [DEFAULT]
◇ `NMAX_ITER_ORTHO=nio` (5) [DEFAULT]
◇ `PREC_LANCZOS=pl` (1.10⁻⁸) [DEFAULT]
◇ `NMAX_ITER_QR=nim` (30) [DEFAULT]

the first two parameters allow, respectively, to adjust the accuracy of orthogonalization and the number of reorthogonalisations in the method of Lanczos to obtain independent vectors generating the subspace (cf [R5.01.01] §6).

The third is a parameter of adjustment to determine the nullity of a term on the surdiagonale of the matrix tridiagonal characterizing the reduced problem obtained by the method of Lanczos. It is right a criterion of deflation and not, as opposed to what could let believe its name, a quality standard of the modes.

The last fixes the maximum nombre of iterations for the resolution of the system reduced for method QR ([R5.01.01] appendix 1).

Note:

- *During the first transitions, 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.*

3.4.3 Operands of the method of Bathe & Wilson (if `METHODE= `JACOBI``)

◇ `PREC_BATHE=pmat` (1.10⁻¹⁰) [DEFAULT]
◇ `NMAX_ITER_BATHE=nbat` (40) [DEFAULT]
◇ `PREC_JACOBI=pjaco` (1.10⁻²) [DEFAULT]
◇ `NMAX_ITER_JACOBI=njaco` (12) [DEFAULT]

the first two parameters allow, respectively, to adjust the accuracy of convergence and the maximum number of allowed iterations of the method of Bathe & Wilson (cf [R5.01.01] §8).

The two others adjust the accuracy of convergence and the maximum number of iterations of the method of JACOBI (cf [R5.01.01] appendix 3). This total modal solver is used to compute: the eigen modes of the matrix projected by Bathe & Wilson.

Note:

• During the first transitions, 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.

3.4.4 Operands of the method QZ (if METHODE= 'QZ')

```
◇TYPE_QZ = "QZ_SIMPLE" [DEFAULT]
           /"QZ_EQUI"
           /"QZ_QR"
```

This parameter makes it possible to choose one of the alternatives of the algorithm QZ proposed by LAPACK. The first choice ("QZ_SIMPLE") indicates the basic method, the second ("QZ_EQUI") adds to him a preprocessing of balancing of the terms of the matrix. That often improves quality of the modes but, *a contrario*, if the matrix presents very small terms due to rounding errors, this phase generates parasitic modes then.

As for the third choice ("QZ_QR"), it is reserved for the positive definite symmetric case (real stiffness matrix, condition of Dirichlet without Lagrange, not of buckling or damping). It is much faster than the preceding options.

3.5 Key word CALC_FREQ

◇ CALC_FREQ=_F (...)

Factor key word for the definition of the parameters of computation of the eigen modes and their number.

3.5.1 Operand FREQ

```
◆FREQ=1_f
◇TABLE_FREQ=table_f
```

List of the frequencies (can be used only if TYPE_RESU= 'DYNAMIQUE'): its use depends on the OPTION selected.

OPTION='BANDE' One expects two values (f_{min}, f_{max}) which define the tape of search

OPTION='CENTER' One expects only one value of frequency

the values stipulated under this key word must be positive strictly increasing.

With the option "BANDAGES", one starts by operating a coûteux2En² test of Sturm type in order to determine the number of modes contained in the tape (cf [R5.01.04]). If one has, as a preliminary, carried out a calibration of the zone of interest by a INFO_MODE, one can save part of this cost of computation. With this intention, one re-uses the array generated by 1'INFO_MODE. The limits

(f_{min}, f_{max}) above definite make it possible to select one or more lines of the aforesaid array.

For example, if the array were generated by

a INFO_MODE+FREQ= ($f_0, f_1, f_2, f_3, f_4, f_5$),

one can pool part of the cost computation of it while posing in MODE_ITER_SIMULT+'BANDE', FREQ=formule ($f_{min}=f_1, f_{max}=f_4$). The stage of pretreatment of MODE_ITER_SIMULT then

2 average 20/30% of the cost total computation of the operator.

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

will carry out the test of Sturm type but, with core, will not detect in the array the sub-bands included in the interval. Maybe, here:

$$[f_1, f_2] \cup [f_2, f_3] \cup [f_3, f_4] .$$

One then just will add the numbers of modes corresponding to each subintervals to deduct the number of modes from it total to search.

This sequence really makes it possible to reduce the overcost of the initial calibration by `INFO_MODE`. This one can become the rule before any computation of modes.

Remarks concerning sequence `INFO_MODE+MODE_ITER_SIMULT+' BANDE'`:

- The limits of selection (f_{min}, f_{max}) must correspond exactly to those having been used to generate the initial `INFO_MODE` (with `VERI_MODE/PREC_SHIFT % close3`).
- The selection of the lines of the array is carried out compared to the initial values of the frequencies. But if they underwent shifts (because they were too close to eigen modes), the array traces also these values after shifts (values `FREQ_MIN/MAX` versus `BORNE_MIN/MAX_EFFECT`). These are of course the last shifted values which are transmitted to the algorithmy of `MODE_ITER_SIMULT`. This strategy preserves thus, at the same time, the ergonomics of the software option and the consistency of the behaviors: a `MODE_ITER_SIMULT+' BANDE'` provides the same one result, whether it starts its phase of pretreatment with or without precalculated array.
- If one of the limits of selection had to be shifted (in the preliminary `INFO_MODE`), the phase of preprocessing emits an `ALARME` to reproduce the same behavior as for a standard computation.
- The array should comprise neither hole, nor covering, or else it is rejected! But this case cannot normally occur with a card resulting from `INFO_MODE`. This rule makes it possible to preserve the robustness of the algorithmic diagram: one wants to miss no frequency!

3.5.2 Operand `AMOR_REDUIT`

◇ `AMOR_REDUIT=1_a`

Value of the reduced damping which makes it possible to define the eigenvalue complexes (the "shift") around which one seeks the closest eigenvalues (cf [R5.01.01] §5.4). This option can be used only in the frame of a modal problem to complex modes: QEP or GEP with asymmetric real matrixes or with A symmetric complex.

`OPTION=' CENTER'`

One expects only one value of reduced damping

the value stipulated under this key word must be positive and be ranging between 0 and 1. In buckling, that does not have any interest.

3.5.3 Operand `NMAX_FREQ`

◇ `NMAX_FREQ=nf` (10 if `OPTION=' PLUS_PETITE'`, 1 if `OPTION=' PLUS_GRADE'`)
[DEFAULT]

maximum Number of eigenvalues to calculating.

This key word is ignored with the option "BANDAGES" because one then calculates all the eigenvalues contained in the stipulated tape.

In the two cases, if `nf` is strictly higher than many "degrees of freedom-credits", `nactif` (cf [R5.01.01] §3.2), then one forces it to take this value ceiling.

3 sort criterion is into relative, except when the required limit is close to zero. It becomes an absolute criterion then.

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

3.6 Key word CALC_CHAR_CRIT

◇ CALC_CHAR_CRIT=_F (...)

Factor key word for the definition of the parameters of computation of the eigen modes and their number.

3.6.1 Operand CHAR_CRIT

◆ CHAR_CRIT=l_c

◇ TABLE_CHAR_CRIT=table_c

List of the critical loads (can be used only if TYPE_RESU= 'MODE_FLAMB' or TYPE_RESU= 'GENERAL'): its use depends on the selected option.

OPTION=' BANDE ' One expects two values $(\lambda_{min}, \lambda_{max})$ which define the tape of search

OPTION=' CENTER ' One expects only one value of critical load

the values stipulated under this key word are positive or negative. In dynamics and QEP that does not have any interest.

With the option "BANDAGES", one starts by operating a coûteux⁴ test of Sturm type in order to determine the number of modes contained in the tape (cf [R5.01.04]). If one has, as a preliminary, carried out a calibration of the zone of interest by a INFO_MODE, one can save part of this cost of computation. With this intention, one re-uses the array generated by l'INFO_MODE. The limits $(\lambda_{min}, \lambda_{max})$ above definite make it possible to select one or more lines of the aforesaid array.

For example, if the array were generated by

INFO_MODE+CHAR_CRIT=formule $(\lambda_0, \lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5)$,

one can pool part of the cost computation of it while posing in MODE_ITER_SIMULT+' BANDE ', CHAR_CRIT=formule $(\lambda_{min}=\lambda_1, \lambda_{max}=\lambda_4)$. The stage of pretreatment of MODE_ITER_SIMULT then will carry out the test of Sturm type but, with care, will not detect in the array the sub-bands included in the interval. Maybe, here:

$[\lambda_1, \lambda_2] \cup [\lambda_2, \lambda_3] \cup [\lambda_3, \lambda_4]$.

One then just will add the numbers of modes corresponding to each subintervals to deduct the number of modes from it total to search.

This sequence really makes it possible to reduce the overcost of the initial calibration by INFO_MODE. This one can become the rule before any computation of modes.

Remarks concerning sequence INFO_MODE+MODE_ITER_SIMULT+' BANDE ':

- The limits of selection $(\lambda_{min}, \lambda_{max})$ must correspond exactly to those having been used to generate the initial INFO_MODE (with VERI_MODE/PREC_SHIFT % close ⁵).
- The selection of the lines of the array is carried out compared to the initial values of the frequencies. But if they underwent shifts (because they were too close to eigen modes), the array traces also these values after shifts (values CHAR_CRIT_MIN/MAX versus BORNE_MIN/MAX_EFFECT). These are of course the last shifted values which are transmitted to the algorithm of MODE_ITER_SIMULT . This strategy preserves thus, at the same time, the ergonomics of the software option and the consistency of the behaviors: a MODE_ITER_SIMULT+' BANDE ' provides the same one result, whether it starts its phase of pretreatment with or without precalculated array.

⁴ average 20/30% of the cost total computation of the operator.

⁵ sort criterion is into relative, except when the required limit is close to zero. It becomes an absolute criterion then.

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

- If one of the limits of selection had to be shifted (in the preliminary `INFO_MODE`), the phase of preprocessing emits an `ALARME` to reproduce the same behavior as for a standard computation.
- The array should comprise neither hole, nor covering, or else it is rejected! But this case cannot normally occur with a card resulting from `INFO_MODE`. This rule makes it possible to preserve the robustness of the algorithmic diagram: one wants to miss no frequency!

3.6.2 Operand `NMAX_CHAR_CRIT`

`◇NMAX_CHAR_CRIT=nf (10) [DEFAULT]`

maximum Number of critical loads to calculating.

This key word is ignored with the option `"BANDAGES"` because one then calculates all the eigenvalues contained in the stipulated tape.

In the two cases, if `nf` is strictly higher than many "degrees of freedom-credits", `nactif` (cf [R5.01.01] §3.2), then one forces it to take this value ceiling.

3.7 Operand `APPROCHE`

`◇APPROCHE=/ "REEL" [DEFAULT]`
`/"IMAG"`
`/"COMPLEXE" (only with Sorensen)`

This key word defines the type of approach (real, imaginary or complex) for the choice of pseudo-produced scalar of the QEP used with the method of Lanczos or that of Sorensen (cf [R5.01.02]). This operand does not have a meaning that for the analysis of free vibrations of a damped structure or revolving (complex eigen modes; key word `MATR_C` must be indicated). In buckling, (`TYPE_RESU= 'MODE_FLAMB'`) that does not have any interest.

Note:

- Into quadratic, with the method of Lanczos only approach `"IMAG"` is compatible with a frequential limit null (`"OPTION=PLUS_PETITE"` or `"CENTER"` with $f=0$). With Sorensen, none is compatible.

3.8 Operand `OPTION`

`◇OPTION=`
`"BANDAGES"` One searches all the eigenvalues in a given tape. This tape is defined by the argument of `FREQ=formule (f_{min}, f_{max})` or that of `CHAR_CRIT=formule ($\lambda_{min}, \lambda_{max}$)`. Option only available in GEP to symmetric real matrixes.

`"CENTER"` One searches the `NMAX_FREQ` the eigenvalues closest to the frequency f (argument of the `FREQ=formule` key word f) or closest to the critical load λ (argument of the `CHAR_CRIT=formule` key word λ).

`"PLUS_PETITE"` One searches the `NMAX_FREQ` smaller eigenvalues or the
[DEFAULT] `NMAX_CHAR_CRIT` the smallest critical loads.

“PLUS_Grande” One searches the `NMAX_FREQ` greater eigenvalues.
Option usable only in case `TYPE_RESU=' DYNAMIQUE'`, for a generalized problem, with symmetric real matrixes.
The roles of the stiffness matrixes and mass are inverted in a transparent way for the user.
Rq: it can be useful to disconnect the test of STURM TYPE in operand `VERI_MODE`. Indeed, in the middle of the algorithm, before being converted into physical eigenfrequencies, the eigenvalues can be very small and very close.

“TOUT” One seeks all the modes associated with physical degrees of freedom.
Option usable only with the method QZ.

See [R 5.01.01/02] §2.5/3.8.

3.9 Operands `SEUIL_FREQ/CHAR_CRIT`, `PREC_SHIFT`, `NMAX_ITER_SHIFT`

```
# IF TYPE_RESU=' DYNAMIQUE'
  ◊PREC_SHIFT=p_shift           (0.05)      [DEFAULT]
  ◊SEUIL_FREQ=f_seuil          (0.01)      [DEFAULT]
  ◊ NMAX_ITER_SHIFT=n_shift     (3)         [DEFAULT]

# IF TYPE_RESU=' MODE_FLAMB' or "GENERAL"
  ◊PREC_SHIFT=p_shift           (0.05)      [DEFAULT]
  ◊SEUIL_CHAR_CRIT=c_seuil      (0.01)      [DEFAULT]
  ◊ NMAX_ITER_SHIFT=n_shift     (3)         [DEFAULT]
```

the course of a modal computation in this operator requires the factorization LDL^T of dynamic matrixes $Q(\lambda)$ of the type (cf [R 5.01.01/02] §2.5/3.8)

$$Q(\lambda) := A - \lambda B \quad (\text{GEP})$$

$$Q(\lambda) := \lambda^2 B + \lambda C + A \quad (\text{QEP})$$

These factorization are dependant on numerical 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 maximum of this loss is higher than `ndeci6Valor`⁶, the matrix is supposed to be singular and one seeks a shifted value of the shift getting an invertible matrix.

For GEPs, parameters `SEUIL_*` make it possible to define “the zero modal one”, i.e. the value in on this side which it is considered that an eigenvalue is null. In corollary, in certain operator salaries, if the difference between two eigenvalues is lower than this figure, one considers that they are confused. It is thus necessary to adjust this value according to the average amplitude of the required modes.

If one is in dynamics one transforms this value into pulsation

$$omecor = (2\pi f_seuil)^2$$

while in buckling one keeps it such as it is

$$omecor = c_seuil$$

For QEPs, this value of “the zero modal one” is used during the sort carried out with resulting from modal computation. During this sort, one seeks to determine if a mode is real (it is not retained), complex combined (one keeps that of positive imaginary part) or complex odd (it is not retained). Two formula λ_1, λ_2 are regarded as combined if

$$|\lambda_1 - \bar{\lambda}_2| < omecor$$

⁶ built-in via parameter `NPREC` of the key word `solver` (by default `ndeci=8`).

Warning : The translation process used on this website is a “Machine Translation”. It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

Note:

- A mode is regarded as reality if its imaginary part is lower than $SEUILR=1E-7$ (value into tough initialized in the routines of sort `wp*vec.f`). When
- modes were sorted like purely real or spoiled complexes, an informational message or an alarm appears (`ALGELINE4_87/88`) according to the cases.

Other parameters, `PREC_SHIFT` and `NMAX_ITER_SHIFT`, are related to the algorithm of shift of the limits of the interval formulates $[f_{min}, f_{max}]$ [R5.01.04] §3.2), when one realizes that those are very close to an eigenvalue. Coarsely these limits formulates f_{min} formulates λ_{min} buckling) or formulates f_{max} . formulates λ_{max} are then shifted towards the outside of the segment of `p_shift%`. If the dynamic matrix thus rebuilt is always considered to be "numerically singular", one again Re-shifts after having emitted an `ALARME`. One tries this shift `n_shift` time. formulates

$$\lambda_{min}^- = \lambda_{min} - \max(omecor, 2^{(i-1)} \times p_{shift} \times |(\lambda_{min})|) \quad \text{attempt) formula}$$
$$\lambda_{max}^- = \lambda_{max} + \max(omecor, 2^{(i-1)} \times p_{shift} \times |(\lambda_{max})|) \quad \text{attempt) In fact}$$

, in dynamics as in buckling the shift takes place same way. Stricto - *censu*, in dynamics these are thus not the frequencies that one shifts, but pulsations. Another accuracy, the shift is in fact, by preoccupations with an effectiveness, dichotomic: `p_shift%` the first time, `2xp_shift%` second time etc This process must make it possible quickly to move away from the "zone of singularity" to lower costs. A contrario, one should not too much increase the values of these parameters, because through shifts, the resulting limits can prove to be very different from the initial limits. Moreover

, to remain coherent with "the zero modal one" (noted `omecor` here) : One

- does not shift a value lower than this minimum (from where the max in the formulas above), So
- upon the departure, the measured limit is lower than this "zero" formula $|\lambda| < omecon$ absolute value) one fixes it at more or less this value (according to whether this limit is positive or negative). One then allows any more no shift. Note:

- A limit of the interval formula σ close to an eigenvalue, when factorization `LDLT` of the dynamic matrix associated with this limit (for example that of a `GEP` is written formula $\mathbf{Q}(\sigma) := \mathbf{A} - \sigma \mathbf{B}$ is led to a loss of decimal of more than `NPREC` digits (value parameterized under the key word `solver`). While exploiting the value of this parameter (`NPREC=7, 8 or 9`), one can then avoid the expensive refactorisations which these shifts imply when this numerical singularity is not very marked. In the same way
- , while exploiting the numerical parameters of the linear solvers (for example: `METHODE`, `RENUM`, `PRETRAITEMENTS...`), one can also influence this criterion of singularity. One
- implements this technique of shift in two cases: computation of a test of Sturm type (pre and/or postprocessing) and construction of the dynamic matrix of work. In the event of failure of the algorithm of shift: in the first case, one emits an `ALARME`, in the second, one stops in `ERREUR_FATALE`.
Operand

3.10 DIM_SOUS_ESPACE ◇

```
DIM_SOUS_ESPACE=des ◇  
COEF_DIM_ESPACE=mse EXCLUDED  
("DIM_SOUS_ESPACE", "COEF_DIM_ESPACE") If
```

key word `DIM_SOUS_ESPACE` is not indicated or is initialized with a value strictly lower than the number of required frequencies `nf`, the operator automatically calculates an acceptable dimension for the subspace of projection (cf §5.2 of this document and [R5.01.01] §5.3) to assistance `COEF_DIM_ESPACE`. Thanks to

given of this multiplicative factor, `mse`, one can project on a space whose size is proportional to the number of frequencies contained in the interval of study. In the encapsulation of `MODE_ITER_SIMULT`, `MACRO_MODE_MECA` [U 4.52.02], one can thus optimize the size of the subspaces which remains proportional to the number of required frequencies: the subspaces rich in eigenvalues thus do not penalize poorest (in term of CPU). One

can however arbitrarily fix the size of this subspace, via the value of the `catch` by the key word `DIM_SOUS_ESPACE` (which must be higher than `nf` to be taken into account). In

the two cases, if the size of the subspace of projection `ndim` is strictly higher than the number of "degrees of freedom-credits", `nactif` (cf [R5.01.01] §3.2), then one forces it to take this value ceiling. Note:

If

- one uses the method of Sorensen (IRAM) and that $ndim - nf < 2$, of the data-processing requirements numérique - force to impose $ndim = nf + 2$. Into quadratic one works on a real problem of double size: $2 * nf$, $2 * ndim$. These
- parameters are useless for the method "QZ". Key word

3.11 VERI_MODE ◇

`VERI_MODE=F` (... Key word
factor for the definition of the parameters of the checking of the eigen modes ([R5.01.01] §3.8).
Operand

3.11.1 STOP_ERREUR ◇

`STOP_ERREUR="/OUI' [DEFAULT]/"`
`NON` Makes it possible

to indicate to the operator if it must stop ("OUI") or continue ("NON") if one of criteria `SEUIL` or `STURM TYPE` (only with `MODE_ITER_SIMULT`) is not checked. By default

the concept of output is not produced. Operand

3.11.2 SEUIL ◇

`SEUIL=r (1.10-6) [DEFAULT] tolerance`

Level for the error norm 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). See also parameter `STOP_ERREUR`.
Operand

3.11.3 STURM TYPE ◇

`STURM="/ "OUI' [DEFAULT]/"`
`NON` Checking

known as of `STURM TYPE` ("OUI") allowing to make sure that the algorithm used in the operator determined the exact number of eigenvalues in the interval of search (§3.5/6/8 [R5.01.01]). This option has interest only in GEP with real modes (thus not with complex **K** and asymmetric matrixes). See also parameter `STOP_ERREUR`. Operand

3.11.4 PREC_SHIFT ◇

```
PREC_SHIFT=prs (0.05 ) [DEFAULT ] This
```

parameter (which is a percentage) makes it possible to define an interval containing the calculated eigenvalues, for which the checking of Sturm type will be carried out ([R5.01.01] algorithm n°2). It is also used to select the lines of the array provided in the event of sequence `INFO_MODE+MODE_ITER_SIMULT+' BANDE'` (cf key words `COUNTS_FREQ/CHAR_CRIT`). This option has interest that in GEP with real modes. Operand

3.12 STOP_BANDE_VIDE ◇

```
STOP_BANDE_VIDE="/"OUI' [DEFAULT ]/"  
NON" "OUI'
```

stops computation if no eigenvalue is detected in the tape stipulated by the user: an exception (named `BandeFrequenceVide`) is emitted. She can be treated to continue the course of the study. One can find an example under the case test `SDLL 11a`: `try`

```
: MODE  
1=MODE_ITER_SIMULT (MATR_RIGI=K_ASSE, MATR_MASS=M_ASSE,  
CALC  
_FREQ=_F (OPTION=' BANDE', FREQ  
= (100. , 200.)) except  
aster.BandeFrequenceVideError: MODE  
1=MODE_ITER_SIMULT (MATR_RIGI=K_ASSE, MATR_MASS=M_ASSE,  
CALC  
_FREQ=_F (OPTION=' BANDE',  
FREQ  
= (200. , 3500. ,)) "NON
```

" computation (emission only of one `ALARME`) does not stop if no eigenvalue is detected in the tape stipulated by the user. This

key word is used in macro-command `MACRO_MODE_MECA [U 4.52.02]` in order to allow the absence of eigenvalues in a tape of search. This option does not have interest with the method `QZ`. Operand

3.13 INFO ◇

```
INFO=/1 [DEFAULT ]/2
```

Indicates

the level of printing in the message file . 1:

`Pri` on the file "MESSAGE" of the eigenvalues, their modal position, reduced damping, the error norm a posteriori and certain useful parameters to follow the course of computation (cf §5.2) 2:

`Pri` rather reserved for the developers. Operand

`nti`
`ng`

3.14 TITER ◇

```
TITER=ti Titrate
```

attached to the product concept by this operator [U4.03.01]. Phase

4 of checking One

checks according to the options: OPTION

- = ' BANDE '
the argument of key word `FREQ` or key word `CHAR_CRIT` must provide exactly two values ,
OPTION
- = ' CENTER '
the argument of key word `FREQ` or of key word `CHAR_CRIT` must provide exactly only one
value, OPTION
- = ' PLUS_PETITE '
the argument of key word `FREQ` or of key word `CHAR_CRIT` , is ignored. If

the precise details and the maximum numbers of iterations are unrealistic (for example precise details lower than the accuracy machine or negative nombres of iterations), computation is not carried out.
Stage of execution

5 Checking

5.1

the matrixes, **A** (and **B**) **C** arguments of key words (MATR_A/MATR_RIGI) and (MATR_B/MATR_MASS/MATR_RIGI_GEOM) (and MATR_C/MATR_AMOR), must be coherent between them (i.e. to lean on the same classification and the same mode of storage). Actions

5.2 by default If

key word DIM_SOUS_ESPACE is not indicated or is initialized with a value strictly lower than the number of required frequencies `nf` (operand NMAX_FREQ), the operator automatically calculates an acceptable dimension for the subspace of projection via the empirical formulas (cf §3.6.7):
METHODE

```
= ' SORENSEN' ndim  
=MIN (MAX (2+nf, mse*nf), nactif) with mse =2 by default. METHODE
```

```
= ' TRI_DIAG' ndim  
=MIN (MAX (7+nf, mse*nf), nactif) with mse =4 by default. METHODE
```

```
= ' JACOBI' ndim  
=MIN (MAX (7+nf, mse*nf), nactif) with mse =2 by default. where  
nactif is the number of active degrees of freedom (i.e. the nombre total of degrees of freedom minus  
the number of degrees of freedom of LAGRANGE and less the number of linear relations which bind  
degrees of freedom between them, [R5.01.01] §3.2) and mse is the factor of proportionality fixed by  
COEF_DIM_ESPACE . If
```

a GEP is solved, the dimension of the subspace is doubled. The values of these various parameters are printed in the message file . Modal

6 parameters Normalizes modal Position modes In

output of this operator, the eigen modes real or complex are standardized with largest of the components which is not a LAGRANGE multiplier . To choose another norm, it is necessary to use command `NORM_MODE` [U 4.52.11]. In the case of

a dynamic computation, the data structure `_meca_* mode`, contains, besides the frequencies of vibration and of the associated modal deformed shapes, of the modal parameters (generalized mass, generalized stiffness, participation factor, effective mass). One will find the definition of these parameters in [R5.01.03]. In the case of

a linear computation of buckling, the data structure `_flamb mode`, contains only the associated critical loads and the deformed. In the case of

a generalized symmetric real matrix dynamic computation, the modal position corresponds to the position of the mode in the group of the spectrum defined by the initial matrixes. In all the other cases, the modal positions are allotted of 1 to `nf` (`nf` being the number of modes selected) by classifying them by order ascending algebraic. All the modal positions are thus positive. Optimization

7 of performances CPU Parallelism

7.1 of the linear solver The computation

modal calls upon a linear solver. If one chooses the linear solver MUMPS with the key word `factor solver`, operand `METHODE = ' MUMPS'`, one can activate his parallel operation. It is necessary for that to use a parallel version of Code_Aster, and to inform the number of processors to be used in ASTK (mitre "Options"). Empirically, the use of a processor per slice from 105 to 106 degrees of freedom which comprises the model, gives of good performances. In parallel, one recommends also the parameter setting `RENUM = ' QAMD'`. Computation

7.2 of the modes by sub-bands If

the problem with treating is a GEP and that one searches many modes on a given tape or that the number of degrees of freedom of the model is high (> 105), it is advised to cut out the tape of total search in several sub-bands, from 40 to 80 modes, the most balanced possible. The computation will be thus more robust and faster, even by calling séquentiellement a `MODE_ITER_SIMULT` for each sub-band. For

a better ergonomics, these calls to `MODE_ITER_SIMULT` for each sub-band can be realized in an automatic and transparent way for the user thanks to macro-command `MACRO_MODE_MECA` [U 4.52.02]. This macro-command makes it possible moreover to parallel the processing of the various sub-bands, generating considerable gains on performances CPU (factor which can reach 10 to 20 on the computing time, and several tens of for hundred on the peak report). For

more details, one will refer to generic documentations [U2.08.06] on parallelism, and [U2.06.01] on the computation of eigen modes. Printing of results

8

to display the modal parameters associated with each mode and the coordinated with the modes, it is necessary to use operator IMPR_RESU [U4.91.01] in the following way: Display

- of the modal parameters only in the form of array: IMPR_RESU

```
(RESU=_F (RESULTAT=mode, TOUT
          _PARA= ` OUI', TOUT
          _CHAM= `NON'));
Display
```

- of the modal parameters and the eigenvectors: IMPR_RESU

```
(RESU=_F (RESULTAT=mode, TOUT
          _PARA= `OUI', TOUT
          _CHAM= `OUI')); Sort
```

9 of Characterization modes of `_meca_* mode` For example

, during seismic requests in modal analysis, modal base used must contain the modes which have an important unit effective mass in the direction of the seisme.

Command `EXTR _MODE [U4.52.12]` makes it possible to extract in a data structure of type `_meca_* mode` of the modes which check a certain criterion and of concatenate several data structures of type `_meca_* mode`.

A macro-command, making it possible to connect commands `MODE_ITER_SIMULT` , `NORM_MODE` and `EXTR _MODE` was created: `MACRO_MODE_MECA [U4.52.02]`. Computation

10 examples

10.1 of the 5 eigen modes closest to a given frequency () mode 100 Hz

```
=MODE_ITER_SIMULT (MATR_RIGI=rigid, MATR
                    _MASS=masse, CALC
                    _FREQ=_F (OPTION= `CENTER',
FREQ
                                =100., NMAX
                                _FREQ=5)) ;
Computation
```

10.2 of the critical loads contained in a tape mode

```
=MODE_ITER_SIMULT (MATR_RIGI=rigid, MATR
                    _RIGI_GEO=riggeo, TYPE
                    _RESU= `MODE_FLAMB', CALC
                    _FREQ=_F (OPTION= `BANDE',
TANK
                                _CRIT= (- 1.E8,1.5E8)) );
Sequence
```

10.3 INFO `_MODE+MODE_ITER_SIMULT` (extracted from SDLS 504a) nbmod

```
1 = INFO _MODE (... TYPE
              _MODE=' MODE_FLAMB', TANK
              _CRIT= (- 1.E+6, - 5.E+5,0.0, 1.E+5,1.1E+6,)) RESULT

0=MODE_ITER_SIMULT (... CALC
                    _CHAR_CRIT=_F (OPTION=' BANDE', TABLE_CHAR_CRIT=nbmod1, TANK
                    _CRIT= (- 1.E+06,1.E+05)), TYPE
                    _RESU=' MODE_FLAMB')
```