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## Operator MODE\_ITER\_SIMULT

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### 1 Goal

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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 operators (and their macros): `MODE_ITER_SIMULT` and `MODE_ITER_INV`[U4.52.04].

**first**, who 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 clean modes (typically a half-dozen) or when one wishes to possibly refine some estimates (coming from `MODE_ITER_SIMULT`).

`MODE_ITER_SIMULT` determine one **together of clean modes**, either by a method of type subspace (Bathe & Wilson, Lanczos or Sorensen) or by a global method of the type QR (QZ for the small problems). Its four methods are accessible to treat one **Standard GEP** (symmetrical reality): classical dynamic calculation (without damping and gyroscopic effect) or problem of buckling of Euler.

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

- **To gauge** zones of interest by one `INFO_MODE` [U4.52.01] initial on a list of frequencies (resp. critical loads) given,
- To look at the numbers of associated clean modes,
- **To start again** one or more calculations `MODE_ITER_SIMULT+OPTION=' BANDE'` while testing **to balance the sub-bands and while re-using** `sd_table` generated by `INFO_MODE`. To optimize performances CPU, it is also possible to parallel calculations on the sub-bands thanks to the operator `CALC_MODES + OPTION=' BANDE'` [U4.52.02] in parallel, which can get a profit 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 nonsymmetrical matrix), the spectrum becomes complex. The chaining `INFO_MODE+MODE_ITER_SIMULT` is not then possible any more. Certain keywords or values become without object ( `OPTION=' BANDE'`, `VERI_MODE/STURM...` ) and only methods Sorensen, Lanczos or QZ remain available.

This operator produces one concept `mode_meca_*` (dynamic case) or `mode_flamb` (case buckling of Euler, only in QEP) according to the value indicated in the keyword `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 the macro-order `CALC_MODES` with the option `'BAND'` cut out in several sub-bands [U4.52.02].

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## 2 Syntax

mode\_ [\*] =MODE\_ITER\_SIMULT

### # Standard of problem

◇ 'DYNAMIC' TYPE\_RESU= [DEFECT]  
/ 'MODE\_FLAMB'  
/ 'GENERAL'

# If TYPE\_RESU=  
'DYNAMIQUE'

### # Characteristic of calculation

( ◇ 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= 'CENTERS'  
/ 'BAND'  
/ 'PLUS\_PETITE' [DEFECT]  
/ 'PLUS\_GRANDE'  
/ 'ALL' (only with QZ)  
# If OPTION= 'PLUS\_PETITE'  
◇ NMAX\_FREQ=/10 [DEFECT]  
/nf [I]  
# If OPTION= 'PLUS\_GRANDE'  
◇ NMAX\_FREQ=/1 [DEFECT]  
/nf [I]  
# If OPTION= 'CENTRE'  
◇ FREQ=l\_f [l\_R]  
◇ AMOR\_REDUIT=l\_a [l\_R]  
◇ NMAX\_FREQ=/10 [DEFECT]  
/nf [I]  
# If OPTION= 'BANDE'  
◇ FREQ=l\_f [l\_R]  
◇ TABLE\_FREQ=table\_f table\_sdaster  
)

### # Parameter suitable for the QEP

◇ APPROCHE= / 'REAL' [DEFECT]  
/ 'IMAG'  
/ 'COMPLEX' (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')

### # For pre and postprocessings

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



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

## # Characteristic of calculation

```
(
    ♦ 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=/'CENTERS'
        / 'BAND'
        / 'PLUS_PETITE' [DEFECT]
        / 'ALL' (only with QZ)

# If OPTION= 'PLUS_PETITE'
    ◊ NMAX_CHAR_CRIT= /10 [DEFECT]
    /nf [I]

# If OPTION= 'CENTRE'
    ♦ CHAR_CRIT=l_c [l_R]
    ◊ NMAX_CHAR_CRIT= /10 [DEFECT]
    /nf [I]

# If OPTION= 'BANDE' (only GEP with real symmetrical matrices)
    ♦ CHAR_CRIT=l_c [l_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 [DEFECT]
    /p_shift [R]
◊ NMAX_ITER_SHIFT=/3 [DEFECT]
    /n_shift [I]
◊ SEUIL_CHAR_CRIT=/1.E-2 [DEFECT]
    /c_seuil [R]
```

## # Choice of the method

```
◇ METHODE= / 'SORENSEN' [DEFECT]
           / 'TRI_DIAG' (only real symmetrical GEP/QEP)
           / 'JACOBI' (except in QEP)
           / 'QZ' (problem of smalls <math>10^3</math> degrees of freedom)
```

## # Parameter setting interns methods

### # If METHODE= 'SORENSEN'

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

### # If METHODE= 'TRI\_DIAG'

```
◇ PREC_ORTHO=/1.E-12 [DEFECT]
           /po [R]
◇ NMAX_ITER_ORTHO=/5 [DEFECT]
           /nio [I]
◇ PREC_LANCZOS=/1.E-8 [DEFECT]
           /pl [R]
◇ NMAX_ITER_QR=/30 [DEFECT]
           /nim [I]
◇ OPTION=/ 'WITHOUT' [DEFECT]
           / 'MODE_RIGIDE'
```

### # If METHODE= 'JACOBI'

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

)

### # If METHODE= 'QZ'

```
◇ TYPE_QZ= / 'QZ_SIMPLE' [DEFECT]
           / 'QZ_EQUI'
           / 'QZ_QR' (if GEP with matrices SPD)
```

## # For final checks

```
◇ VERI_MODE= _F (
◇ STOP_ERREUR= / 'YES' [DEFECT]
           / 'NOT'
◇ SEUIL= /1.E-6 [DEFECT]
           /r [R]
◇ PREC_SHIFT=/0.05 [DEFECT]
           /prs [R]
◇ STURM= / 'YES' [DEFECT]
           / 'NOT'
```

)

## # Others

```
◇ STOP_BANDE_VIDE= / 'YES' [DEFECT]
           / 'NOT'
```

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

◇ INFO=/1 [DEFECT]
  /2 [I]
◇ TITRE=ti
);
```

## # Results of the modal problem

```
If MATR_AMOR or MATR_C= [matr_asse_DEPL_R] then [*] - >mode_meca_c
If TYPE_RESU= 'MODE_FLAMB' then [*] - >mode_flamb
If TYPE_RESU= 'GENERAL' then [*] - >mode_flamb
If MATR_RIGI or MATR_A= [matr_asse_DEPL_C] then [*] - >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
If MATR_RIGI or MATR_A= [matr_asse_GENE_C] then [*] - >mode_gene
```

## 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

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

where  $\lambda = (2\pi f)^2$  is the square of the pulsation  $\omega$ ,  $f$  the Eigen frequency and  $\mathbf{x}$  the vector of associated clean displacement. Handled clean modes  $(\lambda, \mathbf{x})$  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  $\mathbf{X}$  associated with this level of critical load  $\mu = -\lambda$ , brings back itself 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  $\mathbf{K}$  matrix of material rigidity and  $\mathbf{K}_g$  geometrical matrix of rigidity. Handled clean modes  $(\lambda, \mathbf{x})$  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  $\lambda$ . To obtain the true critical loads, the variables  $\mu$ , 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  $(\lambda, \mathbf{x})$ .

- 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,  $\mathbf{A}$  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. The complex eigenvalue  $\lambda$  is connected to the Eigen frequency  $f$  and with reduced damping  $\xi$  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
<code>MODE_ITER_INV</code>				Only symmetrical reality (GEP and QEP).
<i>1<sup>ère</sup> phase (heuristics)</i>				
Calculation of some modes	Bisection (without object in QEP).	'SEPARATED'		
Calculation of some modes	Secant Bisection+ (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
<i>2<sup>ième</sup> phase (method of the powers opposite)</i>				
Basic method	Powers opposite	'DIRECT'	Very good construction of clean vectors	Not very robust
Option of acceleration	Quotient of Rayleigh (without object in QEP)	'RAYLEIGH'	Improve convergence	Cost calculation

Operator Perimeter of application	Algorithm	Keyword	Advantages	Disadvantages
<code>MODE_ITER_SIMULT</code> 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 nonsymmetri- cal and with $A$ 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 ( $<10^3$ degrees of freedom). Range in nonsymmetri- cal and with $A$ 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 to refine 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 **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 `MODE_ITER_INV`**

(OPTION=' PROCHE' ). That will make it possible to reduce the standard 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** zones of interest by an initial call to INFO\_MODE on a list of frequencies <sup>1</sup> (resp. critical loads) given,
- **To look at** numbers of clean modes displayed in the file message (or in sd\_table generated),
- **To start again** one or more calculations MODE\_ITER\_SIMULT+OPTION=' BANDE' (or CALC\_MODES) while testing **to balance** bands.

To save time, one can even pool (and it is strongly advised!) part of the cost calculation of INFO\_MODE initial while notifying with MODE\_ITER\_SIMULTS the name of sd\_table generated (cf keywords TABLE\_). This chaining can thus return the overcost of INFO\_MODE negligible and to guide modal calculation effectively.

On the other hand, as soon as one treats a QEP or an atypical GEP (complex and/or nonsymmetrical matrix), the spectrum becomes complex. The chaining INFO\_MODE+MODE\_ITER\_SIMULT is not then possible any more. Certain keywords or values become without object (OPTION=' BANDE', VERI\_MODE/STURM...) and only methods Sorensen, Lanczos or QZ remain available.

**Note:**

- *One strongly advises a preliminary reading of the reference materials [R5.01.01] [R5.01.02] [R5.01.04]. 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/MATR\_A=A  
Assembled, real matrix (symmetrical or not) or complex symmetrical, of type [matr\_asse\*\_R/C] GEP/QEP to be solved.
- ◆ MATR\_MASS/MATR\_RIGI\_GEOM/MATR\_B=B  
Assembled, real matrix (symmetrical or not), of type [matr\_asse\*\_R] GEP/QEP to be solved.
- ◇ MATR\_AMOR/MATR\_C=C  
Assembled, real matrix (symmetrical or not), of type [matr\_asse\*\_R] QEP to be solved.

**Note:**

<sup>1</sup> For reasons of costs calculation, 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.

- If the matrix *With* is complex symmetrical or if one of the matrices *A/B* or *C* is nonsymmetrical real, only the methods of Sorensen and QZ are licit. One cannot then use the option of calculation 'BANDE' and, for the case or the matrix *With* is complex, a worthless frequential terminal ('OPTION=PLUS\_PETITE' or 'CENTER' with  $f = 0$  ).

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

- **In dynamics** (TYPE\_RESU=' DYNAMIQUE'), 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.
- **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' 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 METHOD

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

◇ METHODE=/ 'SORENSEN' [DEFECT]

One uses the method of Sorensen (external package ARPACK) to calculate the clean modes of the GEP or the QEP (cf [R 5.01.01/02] §7/4). Its perimeter includes the real, symmetrical matrices or not, even a matrix *A* complex symmetrical.

◇ / 'TRI\_DIAG'

One uses the method of Lanczos (alternative of Newmann-pipano in GEP, Parlett & Saad in QEP) to calculate the clean modes of the GEP or the QEP (cf [R 5.01.01/02] §6/4). Its perimeter is limited to the real symmetrical matrices.

◇ OPTION=/ 'MODE\_RIGIDE'  
/ 'WITHOUT' [DEFECT]

Keyword 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 calculate 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 worthless but very close to zero.

◇ / `JACOBI`

One uses the method of Bathe & Wilson (then method of Jacobi on the system project) to calculate the clean modes of the GEP (cf [R5.01.01] §8). Its perimeter is limited to the real symmetrical matrices.

◇ / `QZ`

One uses method QZ of external library LAPACK to calculate the clean modes of the GEP or the QEP (cf [R 5.01.01/02] §9/5). Its perimeter includes the real, symmetrical matrices or not, even a matrix  $A$  complex symmetrical. This method of very expensive reference is to be held for the problems smalls ( $<10^3$  degrees of freedom).

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

◇ PREC\_SOREN=ps0 (0.) [DEFECT]

**Note:**

- *The method considers whereas it must work with the smallest possible precision, the "zero machine". To have an order of magnitude of it, in double precision on the machines standards, this value is close to  $2.22 \cdot 10^{-16}$ .*

◇ NMAX\_ITER\_SOREN=nso (20) [DEFECT]

◇ PARA\_ORTHO\_SOREN=porso (0,717) [DEFECT]

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

If the coefficient `porso` is negative, the reorthogonalisation is carried out on all the modes calculated instead of targeting only the modes belonging to the same clean space. Calculation can then be two or three times more expensive.

For more information on the mode of selection of clean spaces one will be able to consult the parameters `SEUIL_FREQ/CHAR_CRIT`.

**Note:**

- *At the time of the first passages, 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<sup>-12</sup>) [DEFECT]  
◇ NMAX\_ITER\_ORTHO=nio (5) [DEFECT]  
◇ PREC\_LANCZOS=pl (1.10<sup>-8</sup>) [DEFECT]  
◇ NMAX\_ITER\_QR=nim (30) [DEFECT]

The first two parameters make it possible, respectively, to adjust the precision of orthogonalisation and the number of réorthogonalisations 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 tridiagonale 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 iteration count for the resolution of the system reduced for method QR ([R5.01.01] appendix 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.*

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

◇	PREC_BATHE =pbat	(1.10 <sup>-10</sup> )	[DEFECT]
◇	NMAX_ITER_BATHE=nbat	(40)	[DEFECT]
◇	PREC_JACOBI=pjaco	(1.10 <sup>-2</sup> )	[DEFECT]
◇	NMAX_ITER_JACOBI=njaco	(12)	[DEFECT]

The first two parameters make it possible, respectively, to adjust the precision 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 precision 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 calculate the clean modes of the matrix projected by Bathe & Wilson.

**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.*

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

```
◇ TYPE_QZ = / 'QZ_SIMPLE' [DEFECT]
           / 'QZ_EQUI'
           / 'QZ_QR'
```

This parameter makes it possible to choose one of the alternatives of algorithm QZ proposed by LAPACK. The first choice ('QZ\_SIMPLE') indicate the basic method, the second ('QZ\_EQUI') he add 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 symmetrical case (matrix of real stiffness, condition of Dirichlet without Lagrange, not of buckling or damping). It is much faster than the preceding options.

## 3.5 Keyword CALC\_FREQ

```
◇ CALC_FREQ=_F (...
```

Keyword factor for the definition of the parameters of calculation of the clean modes and their number.

### 3.5.1 Operand FREQ

```
◆ FREQ=l_f
◇ TABLE_FREQ=table_f
```

List of the frequencies (can be used only if TYPE\_RESU= 'DYNAMIQUE'): its use depends onOPTION chosen.

`OPTION='BAND'` Two values are expected ( $f_{min}, f_{max}$ ) who define the band of research

`OPTION='CENTER'` Only one value of frequency is expected

The values stipulated under this keyword must be positive strictly increasing.

With the option 'BAND', one starts by operating expensive<sup>2</sup> test of Sturm in order to determine the number of modes contained in the band (cf [R5.01.04]). If one has, as a preliminary, carried out a calibration of the zone of interest by one `INFO_MODE`, one can save part of this cost of calculation. With this intention, one re-uses the table generated by `INFO_MODE`. Terminals ( $f_{min}, f_{max}$ ) defined above allow to select one or more lines of the aforesaid table.

For example, if the table were generated by one

$$\text{INFO\_MODE+FREQ} = (f_0, f_1, f_2, f_3, f_4, f_5) ,$$

one can pool part of the cost calculation of it while posing in `MODE_ITER_SIMULT+'BANDE'`, `FREQ=(f_min=f_1, f_max=f_4)`. The stage of pretreatment of `MODE_ITER_SIMULT` then will carry out the test of Sturm but, in the place, will not detect in the table 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 summon the numbers of modes corresponding to each subintervals to deduct the number of modes from it total to search.

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

## Remarks concerning chaining `INFO_MODE+MODE_ITER_SIMULT+'BANDE'`:

- Terminals of selection ( $f_{min}, f_{max}$ ) must correspond exactly to those having been used to generate it `INFO_MODE` initial (with `VERI_MODE/PREC_SHIFT % near3`).
- The selection of the lines of the table is carried out compared to the initial values of the frequencies. But if they underwent shifts (because they were too close to clean modes), the table 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: one `MODE_ITER_SIMULT+'BANDE'` provides the same result, whether it starts its phase of pretreatment with or without precalculated table.
- If one of the terminals of selection had to be shifted (in `INFO_MODE` precondition), the phase of preprocessing emits one `ALARM` to reproduce the same behavior as for a standard calculation.
- The table should comprise neither hole, nor covering, or else it is rejected! But this case cannot normally occur with a map 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 eigenvalues closest (cf [R5.01.01] §5.4). This option cannot be used that within the framework of a modal problem to complex modes: QEP or GEP with nonsymmetrical real matrices or with  $A$  complex symmetrical.

`OPTION='CENTER'` One expects only one value of reduced damping

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

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

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The value stipulated under this keyword 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')  
[DEFECT]

Maximum number of eigenvalues to calculate.

This keyword is ignored with the option 'BAND' because one then calculates all the eigenvalues contained in the stipulated band.

In both cases, if nf 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.

## 3.6 Keyword CALC\_CHAR\_CRIT

◇ CALC\_CHAR\_CRIT=\_F (...)

Keyword factor for the definition of the parameters of calculation of the clean 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 option chosen.

OPTION= 'BAND' Two values are expected ( $\lambda_{min}, \lambda_{max}$ ) who define the band of research

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

The values stipulated under this keyword are positive or negative. In dynamics and QEP that does not have any interest.

With the option 'BAND', one starts by operating expensive<sup>4</sup> test of Sturm in order to determine the number of modes contained in the band (cf [R5.01.04]). If one has, as a preliminary, carried out a calibration of the zone of interest by one INFO\_MODE, one can save part of this cost of calculation.

With this intention, one re-uses the table generated by INFO\_MODE. Terminals ( $\lambda_{min}, \lambda_{max}$ ) defined above allow to select one or more lines of the aforesaid table.

For example, if the table were generated by one

INFO\_MODE+CHAR\_CRIT= ( $\lambda_0, \lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5$ ) ,

one can pool part of the cost calculation of it while posing in MODE\_ITER\_SIMULT+' BANDE', CHAR\_CRIT= ( $\lambda_{min}=\lambda_1, \lambda_{max}=\lambda_4$ ) . The stage of pretreatment of MODE\_ITER\_SIMULT then will carry out the test of Sturm but, in the place, will not detect in the table 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 summon the numbers of modes corresponding to each subintervals to deduct the number of modes from it total to search.

This chaining really makes it possible to reduce the overcost of the initial calibration by INFO\_MODE. This one can become the rule before any calculation of modes.

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

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## Remarks concerning chaining `INFO_MODE+MODE_ITER_SIMULT+'BANDE'`:

- Terminals of selection  $(\lambda_{min}, \lambda_{max})$  must correspond exactly to those having been used to generate it `INFO_MODE` initial (with `VERI_MODE/PREC_SHIFT % near5`).
- The selection of the lines of the table is carried out compared to the initial values of the frequencies. But if they underwent shifts (because they were too close to clean modes), the table 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: one `MODE_ITER_SIMULT+'BANDE'` provides the same result, whether it starts its phase of pretreatment with or without precalculated table.
- If one of the terminals of selection had to be shifted (in `INFO_MODE` precondition), the phase of preprocessing emits one `ALARM` to reproduce the same behavior as for a standard calculation.
- The table should comprise neither hole, nor covering, or else it is rejected! But this case cannot normally occur with a map 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) [DEFECT]

Maximum number of critical loads to calculate.

This keyword is ignored with the option `'BAND'` because one then calculates all the eigenvalues contained in the stipulated band.

In both cases, if `nf` 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.

### 3.7 Operand `APPROACH`

◇ `APPROCHE= / 'REEL'` [DEFECT]  
/ 'IMAG'  
/ 'COMPLEX' (only with Sorensen)

This keyword defines the type of approach (real, imaginary or complex) for the choice of the scalar pseudo-product of the QEP used with the method of Lanczos or that of Sorensen (cf [R5.01.02]).

This operand does not have a direction that for the analysis of the free of a deadened structure or revolving vibrations (complex clean modes; the keyword `MATR_C` must be well informed). 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 worthless frequential terminal (`'OPTION=PLUS_PETITE'` or `'CENTER'` with  $f=0$ ). With Sorensen, none is compatible.

### 3.8 Operand `OPTION`

◇ `OPTION=`

---

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

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`BAND`	One searches all the eigenvalues in a given band. This band is defined by the argument of $FREQ = (f_{min}, f_{max})$ or by that of $CHAR\_CRIT = (\lambda_{min}, \lambda_{max})$ . Option only available in GEP to symmetrical real matrices.
`CENTER`	They are searched $NMAX\_FREQ$ the eigenvalues closest to the frequency $f$ (argument of the keyword $FREQ = f$ ) or closest to the critical load $\lambda$ (argument of the keyword $CHAR\_CRIT = \lambda$ ).
`PLUS_PETITE` [DEFECT]	They are searched $NMAX\_FREQ$ smaller eigenvalues or them $NMAX\_CHAR\_CRIT$ smallest critical loads.
`PLUS_GRANDE`	They are searched $NMAX\_FREQ$ greater eigenvalues. Option usable only in the case $TYPE\_RESU = 'DYNAMIQUE'$ , for a generalized problem, with symmetrical real matrices. The roles of the matrices of rigidity and mass are inverted in a transparent way for the user. Rq: it can be useful to disconnect the test of STURM in the operand $VERI\_MODE$ . Indeed, in the middle of the algorithm, before being converted into physical Eigen frequencies, the eigenvalues can be very small and very close.
`ALL`	One seeks all the modes associated with physical degrees of freedom. Option usable only with method QZ.

See [R 5.01.01/02] §2.5/3.8.

### 3.9 Operands SEUIL\_FREQ/SEUIL\_CHAR\_CRIT, PREC\_SHIFT, NMAX\_ITER\_SHIFT

# IF TYPE_RESU=' DYNAMIQUE'			
◇	PREC_SHIFT	=	p_shift (0.05) [DEFECT]
◇	SEUIL_FREQ	=	f_seuil (0.01) [DEFECT]
◇	NMAX_ITER_SHIFT	=	n_shift (3) [DEFECT]
# IF TYPE_RESU=' MODE_FLAMB' or 'GENERAL'			
◇	PREC_SHIFT	=	p_shift (0.05) [DEFECT]
◇	SEUIL_CHAR_CRIT	=	c_seuil (0.01) [DEFECT]
◇	NMAX_ITER_SHIFT	=	n_shift (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)

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

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

These factorizations are dependent on digital instabilities when the shift  $\lambda$  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  $ndeci^6$ , the matrix is supposed to be singular and one seeks a shifted value of the shift getting an invertible matrix.

For GEPs, the parameters  $SEUIL\_*$  allow to define "the zero modal one", i.e. the value in on this side which it is considered that an eigenvalue is worthless. In corollary, in certain operator salaries, if the difference between two eigenvalues is lower than this figure, one considers that

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

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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 at the time of the sorting carried out with resulting from modal calculation. At the time of this sorting, 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 modes  $\lambda_1, \lambda_2$  are regarded as combined if

$$|\lambda_1 - \overline{\lambda_2}| < omecor$$

## Note:

- A mode is regarded as reality if its imaginary part is lower than  $SEUILR=1E-7$  (value into hard initialized in the routines of sorting).
- When modes were sorted like purely real or spoiled complexes, an informational message or an alarm appears (ALGELINE4\_87/88) according to the cases.
- With the methods of Sorensen and QZ, in standard GEP (symmetrical reality), the parameters \*\_threshold are used to determine if two modes must be orthogonalized or not (when the selective orthogonalisation is activated as it is the case by default, cf. PARA\_ORTHO\_SOREN). Two modes are regarded as “multiples”, therefore with réorthogonaliser, if their modules are all the two lower than  $100*omecor$  or, in the contrary case, if their relative variation is lower than  $omecor$ . This reorthogonalisation is expensive but essential for later projections on modal basis, from where the need for values balanced for this criterion. Normally the fixed values by default are sufficient and they do not have to be often modified.

Other parameters, PREC\_SHIFT and NMAX\_ITER\_SHIFT, are related to the algorithm of shift of the terminals of the interval  $[f_{min}, f_{max}]$  (cf [R5.01.04] §3.2), when one realizes that those are very close to an eigenvalue. Coarsely these terminals  $f_{min}$  (or  $\lambda_{min}$  in buckling) or  $f_{max}$  (resp.  $\lambda_{max}$ ) 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 one ALARM. This shift is tried  $n\_shift$  time.

$$\lambda_{min}^- = \lambda_{min} - \max(omecor, 2^{(i-1)} \times p\_shift \times |(\lambda_{min})|) \quad (\text{l\`eme attempt})$$
$$\lambda_{max}^- = \lambda_{max} + \max(omecor, 2^{(i-1)} \times p\_shift \times |(\lambda_{max})|) \quad (\text{l\`eme attempt})$$

In fact, in dynamics as in buckling the shift takes place same manner. *Stricto-censu*, in dynamics these are thus not the frequencies that one shifts, but pulsations.

Another precision, 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 terminals can prove to be very different from the initial terminals.

Moreover, to remain coherent with “the zero modal one” (noted here  $omecor$ ):

- One does not shift a value lower than this minimum (from where the max in the formulas above),
- So from the beginning, the measured terminal is lower than this “zero”  $|\lambda_*| < omecor$  (in absolute value) one fixes it at more or less this value (according to whether this terminal is positive or negative). One then allows any more no shift.

## Note:

- A terminal of the interval  $\sigma$  is close to an eigenvalue, when factorization LDLT of the dynamic matrix associated on this terminal (for example that of a GEP is written  $Q(\sigma) := A - \sigma B$ ), led to a loss of decimal of more than  $NPREC$  digits (value

parameterized under the keyword *SOLVEUR* ). 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 digital singularity is not very marked.

- In the same way, while exploiting the digital parameters of the linear solvers (for example: *METHOD, RENUM, PRETREATMENTS...*), one can also influence this criterion of singularity.
- One implements this technique of shift in two cases: calculation of a test of Sturm (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 is emitted *ALARM*, in the second, one stops in *ERREUR\_FATALE*.

## 3.10 Operand DIM\_SOUS\_ESPACE

```
◇ DIM_SOUS_ESPACE=des  
◇ COEF_DIM_ESPACE=mse  
EXCLUDED ('DIM_SOUS_ESPACE', 'COEF_DIM_ESPACE')
```

If the keyword *DIM\_SOUS\_ESPACE* is not informed or is initialized with a value strictly lower than the number of frequencies requested *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 the 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, CALC\_MODES* [U4.52.02], 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 catch by the keyword *DIM\_SOUS\_ESPACE* (which must be higher than *nf* to be taken into account).

In both cases, if 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  $ndim-nf < 2$ , data-processing requirements *numérico* - 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 method 'QZ'.

## 3.11 Keyword VERI\_MODE

```
◇ VERI_MODE=_F (...
```

Keyword factor for the definition of postprocessings of checking of the clean modes. These postprocessings relate to the standard of the residue of the modes and the counting of the eigenvalues (cf [R5.01.01] §3.7.4 and [R5.01.02] §2.5.4).

### 3.11.1 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.

## 3.11.2 Operand `THRESHOLD`

◇ `SEUIL=r` (1.10<sup>-6</sup>) [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). See also parameter `STOP_ERREUR`.

## 3.11.3 Operand `STURM`

◇ `STURM= / 'YES' [DEFECT]`  
`/ 'NOT'`

Checking known as of `STURM` ('YES') allowing to make sure that the algorithm used in the operator determined the exact number of eigenvalues in the interval of research ([R5.01.01] §3.5 and 3.7.4). This option thus has interest only in GEP with real modes (not with **K** complex and with nonsymmetrical matrices). See also parameter `STOP_ERREUR`.

## 3.11.4 Operand `PREC_SHIFT`

◇ `PREC_SHIFT=prs` (0.05) [DEFECT]

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

## 3.12 Operand `STOP_BANDE_VIDE`

◇ `STOP_BANDE_VIDE=/ 'YES' [DEFECT]`  
`/ 'NOT'`

'YES' stop calculation if no eigenvalue is detected in the band stipulated by the user: an exception (named `BandeFrequenceVide`) is emitted. It can be treated to continue the course of the study. One can find an example under the case test `SDLL11a`:

```
try:
    MODE1=MODE_ITER_SIMULT (MATR_RIGI=K_ASSE,
MATR_MASS=M_ASSE,
    CALC_FREQ=_F (OPTION=' BANDE',
    FREQ= (100. , 200.))
except aster.BandeFrequenceVideError:
    MODE1=MODE_ITER_SIMULT (MATR_RIGI=K_ASSE,
MATR_MASS=M_ASSE,
    CALC_FREQ=_F
(OPTION=' BANDE',
    FREQ= (200. , 3500. ,)))
```

'NOT' do not stop calculation (emission only of one `ALARM`) if no eigenvalue is detected in the band stipulated by the user.

This keyword is used in the macro-order `CALC_MODES` [U4.52.02] in order to allow the absence of eigenvalues in a band of research. This option does not have interest with method `QZ`.

## 3.13 Operand INFORMATION

◇ INFO=/1 [DEFECT]  
/2

Indicate the level of impression in the file MESSAGE.

- 1: Impression on the file 'MESSAGE' eigenvalues, of their modal position, reduced damping, standard of error a posteriori and certain useful parameters to follow the course of calculation (cf §5.2)
- 2: Impression rather reserved for the developers.

## 3.14 Operand TITLE

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

## 4 Phase of checking

---

One checks according to the options:

OPTION=' BANDE '

The argument of the keyword `FREQ` or of the keyword `CHAR_CRIT` must provide exactly **two** values,

OPTION=' CENTRE '

The argument of the keyword `FREQ` or of the keyword `CHAR_CRIT` must provide exactly **one** only value,

OPTION=' PLUS\_PETITE '

The argument of the keyword `FREQ` or of the keyword `CHAR_CRIT`, is ignored.

If the maximum precise details and numbers of iterations are unrealistic (for example precise details lower than the precision machine or negative iteration counts), calculation is not carried out.

## 5 Production run

---

### 5.1 Checking

Matrices **A** , **B** (and **C** ) arguments of the keywords (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 be based on the same classification and the same mode of storage).

### 5.2 Actions by default

If the keyword DIM\_SOUS\_ESPACE is not informed or is initialized with a value strictly lower than the number of frequencies requested `nf` (operand NMAX\_FREQ), the operator automatically calculates an acceptable dimension for the subspace of projection *via* 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 full number 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 file MESSAGE.

## 6 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 generalized dynamic calculation with symmetrical real matrices, the modal position corresponds to the position of the mode in the whole of the spectrum defined by the initial matrices. In all the other cases, the modal positions are allotted of 1 to `nf` (`nf` being the number of modes retained) by classifying them by order ascending algebraic. All the modal positions are thus positive.

## 7 Optimization of performances CPU

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### 7.1 Parallelism of the linear solvor

Modal calculation calls upon a linear solvor. If one chooses linear solvor MUMPS with the keyword factor `SOLVEUR`, 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 of  $10^5$  to  $10^6$  degrees of freedom which the model comprises, gives of good performances. In parallel, one recommends also the parameter setting `RENUM=' QAMD '`.

### 7.2 Calculation of the modes by sub-bands

If the problem to be treated 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 ( $> 10^5$ ), it is advised to cut out the band of total research in several sub-bands, from 40 to 80 modes, the most balanced possible. Calculation will be thus more robust and faster, even by calling séquentiellement one `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 the macro-order `CALC_MODES` [U4.52.02] with the option `'BAND'` cut out in sub-bands. This macro-order makes it possible moreover to parallel the treatment of the various sub-bands, generating considerable profits 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 calculation of clean modes.

## 8 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'));
```

## 9 Sorting of Characterization modes of mode\_meca\_\*

---

For example, at the time of seismic requests in modal analysis, the modal base used must contain the modes which have an important unit effective mass in the direction of the earthquake.

The order EXTR\_MODE[U4.52.12] allows to extract in a structure of data of the type mode\_meca\_\* modes which check a certain criterion and of concaténer several structures of data of the type mode\_meca\_\*.

The macro-order CALC\_MODES [U4.52.02] makes it possible to connect the orders MODE\_ITER\_SIMULT, NORM\_MODE and EXTR\_MODE.

## 10 Examples

### 10.1 Calculation of the 5 clean modes closest to a given frequency ( 100 Hz )

```
mode=MODE_ITER_SIMULT(MATR_RIGI=rigid,
                       MATR_MASS=masse,
                       CALC_FREQ=_F (OPTION =
'CENTER',
                                     FREQ=100.,
                                     NMAX_FREQ=5 )
                       );
```

### 10.2 Calculation of the critical loads contained in a band

```
mode=MODE_ITER_SIMULT(MATR_RIGI=rigid,
                       MATR_RIGI_GEOM=riggeo,
                       TYPE_RESU= 'MODE_FLAMB',
                       CALC_FREQ=_F ( OPTION=
'BANDE',
                                     CHAR_CRIT= (-
1.E8,1.5E8))
                       );
```

### 10.3 Chaining INFO\_MODE+MODE\_ITER\_SIMULT (extracted from SDLS504a)

```
nbmod1 = INFO_MODE(...
           TYPE_MODE=' MODE_FLAMB',
           CHAR_CRIT= (- 1.E+6, - 5.E+5,0.0, 1.E+5,1.1E+6),)
RESULT0=MODE_ITER_SIMULT(...
           CALC_CHAR_CRIT=_F (OPTION=' BANDE',TABLE_CHAR_CRIT=nbmod1,
           CHAR_CRIT= (- 1.E+06,1.E+05)),
           TYPE_RESU=' MODE_FLAMB'
           )
```