
Macro-command CALC_MODAL

1 Drank

Throw in only one command the entirety of the character string of computation of eigen modes:

- 1.CALC_MATR_ELEM (options "RIGI_MECA", "MASS_MECA" and "AMOR_MECA");
- 2.NUME_DDL;
- 3.ASSE_MATRICE;
- 4.MODE_ITER_SIMULT.

The purpose of this macro-command is offering to the users simple and convivial tools for the computation of the eigen modes of a solid structure without fluid interaction and only for the "dynamic" modes and not for those of buckling. For time the computation of the stiffness matrix is restricted with the case of the symmetric matrixes.

Product only one data structure of the `mode_meca` type if not of damping matrix present or `mode_meca_c` if damping matrix present. The choice of the presence of damping is done with key word `AMORTISSEMENT`.

2 Syntax

```

mod_meca =CALC_MODAL      (

    ♦ MODELS              =mo      ,                [model]
    ◊AMORTISSEMENT       =/"NON"    [DEFAULT]
                          /"OUI"

    ♦CHAM_MATER          =chmat ,                [cham_mater]
    ◊ CHARGE              =char      ,                [char_meca]
    ◊ CARA_ELEM          =caract      ,
[cara_elem]
    ◊ INST                =/tps      ,                [R]
                          /0.0      ,
[DEFAULT]

    ◊ METHODE = "TRI_DIAG"
        ◊ PREC_ORTHO =      1.E-12,                [DEFAULT]
                          /Po,                    [R]
        ◊ NMAX_ITER_ORTHO =      5 ,                [DEFAULT]
                          /nio,                    [I]
        ◊ PREC_LANZOS =      1.E-8,                [DEFAULT]
                          /pl,                     [R]
        ◊ NMAX_ITER_QR =      30,                  [DEFAULT]
                          /nim,                    [I]
        /"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]

        /"SORENSEN"
        ◊ PREC_SOREN =      0 ,                    [DEFAULT]
                          /pso,                      [R]
        ◊ NMAX_ITER_SOREN =      20,                [DEFAULT]
                          /nso,                      [I]
        ◊ PARA_ORTHO_SOREN =      0.717,           [DEFAULT]
                          /porso,                   [I]

        /"QZ"
        ◊ TYPE_QZ = "QZ_SIMPLE",                    [DEFAULT]
                          /"QZ_QR",
                          /"QZ_EQUI",

    ◊MODE_RIGIDE          = "YES",
                          /"NON",                    [DEFAULT]

```

```

    ◇ CALC_FREQ = _F (
      ◇OPTION = "CENTER"
          ◆ FREQ =l_f [l_R]
          ◇ AMOR_REDUIT =l_a [l_R]
          ◇ NMAX_FREQ =/10
[DEFAULT]
          /nf [I]
          / "TAPE"
          ◆ FREQ =l_f [l_R]
          / "PLUS_PETITE" [DEFAULT]
          ◇NMAX_FREQ =/10
[DEFAULT]
          /nf [I]
          / "PLUS_GRADE" [DEFAULT]
          ◇NMAX_FREQ =/1
[DEFAULT]
          /nf [I]

    ◇APPROCHE = "REEL" [DEFAULT]
          / "IMAG"
          / "COMPLEXE"
    ◇ /DIM_SOUS_ESPACE =des [I]
    /COEF_DIM_ESPACE =mse [I]
    ◇ PREC_SHIFT = 0.05 [DEFAULT]
          /PS [R]
    ◇ NMAX_ITER_SHIFT = 3 [DEFAULT]
          /NS [I]
    ◇ SEUIL_FREQ = 1.E-2 [DEFAULT]
          /sf [R]
    ◇ STOP_BANDE_VIDE = "OUI" [DEFAULT]
          /"NON"

    )

    ◇ VERI_MODE = _F (
      ◇STOP_ERREUR = "OUI" [DEFAULT]
          / "NON"
      ◇SEUIL =/rseuil [R]
          /1.E-6 [DEFAULT]
    ◇ STURM TYPE = "OUI"
[DEFAULT]
          / "NON" [l_Kn]
    ◇ PREC_SHIFT =/pshif [R]
          /0.005 [DEFAULT]
    )

    ◇INFO =/1
[DEFAULT]
          /2

    ◇ TITER = title

    )

```

3 Operands

3.1 Operand MODELS

This operand is used to indicate the finite elements which constitute the structure of which have calculates the eigen modes. It is pointed out that the finite elements for the majority are defined in the model.

There are two exceptions:

- Elements of dualisation of the conditions of DIRICHLET, i.e. elements allowing to impose conditions on the degrees of freedom of displacement in mechanics.
- Nodal loading elements .

These elements are defined in a concept of the `char_meca` type.

If one is in a case among both presented above, one must provide the concept `char_meca` corresponding for computation of the elementary matrixes of stiffness with option `RIGI_MECA`.

`◇INST = tps`

the argument `tps` is used when the material characteristics or the loadings depend on time. A rather frequent case is that of a mechanical material depend on the temperature which it even depends on time.

3.2 Key word AMORTISSEMENT

This key word allows the catch in depreciation account. If it is indicated "OUI", then the elementary matrixes D" damping will be calculated with L" option "AMOR_MECA" .

3.3 Operand CHAM_MATER

Name of the material field where the characteristics of the materials of the elements are defined.

3.4 Operand CARA_ELEM

the elementary characteristics are necessary if there exists in the model beam elements, shell or discrete elements or if a reference of anisotropy were defined on solid elements (key word `MASSIF` of the command `AFFE_CARA_ELEM`).

3.5 Operand CHARGE

This operand is to be specified if there are elements for which elementary computations of stiffness (conditions of DIRICHLET) are done.

3.6 Operand INST

the argument `tps` is used when the material characteristics or the loadings depend on time. A rather frequent case is that of a mechanical material depend on the temperature which it even depends on time.

3.7 Key word METHODE

Four methods of resolution are available for the problem to the eigenvalues

the method WILL GO (known as of Sorensen), makes it possible to treat the two types of problems generalized and quadratic. It is the method by default and is based on:

- obtaining a matrix of Hessenberg by means of a factorization of the Arnoldi type
- the computation of the eigenvalues of this problem project by a method QR
- a certain number of restartings allowing to refine the eigenvalues sought by the user, the other eigenvalues necessary to the method being used as auxiliary values.

The method of Lanczos, makes it possible to treat the two types of problems generalized and quadratic. It is based on:

- obtaining a matrix tridiagonal projected via the method of Lanczos,
- the resolution of the system three-diagonal reduced by a method **QR**,

the iterative method of Bathe and valid Wilson only for the generalized problem, is based on:

- construction with each iteration of a problem generalized project moreover small,
- the computation of the eigenvalues of this problem project by a method of Jacobi.

The method QZ

◇ METHODE = "SORENSEN" [DEFAULT]

One uses the method of Sorensen (cf [§5] to compute: [R5.01.01]) the values and eigenvectors of the generalized or quadratic problem. To take into account also the gyroscopic effect.

◇/ "TRI_DIAG"

One uses the method of Lanczos to compute: (then **method** QR on the system project) the values and eigenvectors of the generalized or quadratic problem (cf [§4] [R5.01.01]).

◇/ "JACOBI"

One uses the method of Bathe & Wilson (cf [§6] [R5.01.01]) (then method of Jacobi on the system project) to compute: values and eigenvectors of the generalized problem. This option cannot be used for a quadratic problem.

◇/ "QZ"

One uses the method QZ to deal with the quadratic modal problems taking into account the gyroscopic effect of revolving structures. The mass matrixes, stiffness and damping can be NON-symmetric.

3.7.1 Operands of IRAM (if METHODE = "SORENSEN")

◇ PREC_SOREN=pso (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 [§5.4.2] and

[§6.4] [R5.01.01]) and of the coefficient of orthogonalization of the IGSM of Kahan-Parlett (cf [§11.4] [R5.01.01]).

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.

3.7.2 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 [§5.5.1] [R5.01.01]).

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 (cf [§5.4.1] [R5.01.01]).

The last fixes the maximum nombre of iterations for the resolution of the system reduced by method QR ([§5.5.2] and [§10] [R5.01.01]).

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.

3.7.3 Operands of the method of Bathe & Wilson (if METHODE = "JACOBI")

◇	PREC_BATHE=pbat	(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 [§7] [R5.01.01]).

The two others make it possible to adjust the accuracy of convergence and the maximum number of iterations permitted by the method of JACOBI (cf [§12] [R5.01.01]) which makes it possible to exhume the eigen modes of the matrix projected by the preceding method.

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.

3.7.4 Operands of the method QZ (if METHODE = "QZ")

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

- "QZ_SIMPLE" , algorithm "standard" QZ,
- "QZ_EQUI" , idem but one adds a preprocessing of balancing of the terms of the matrixes. That often improves quality of the modes, but *a contrario* , if the matrixes present very small terms due to rounding errors, this phase generates parasitic modes.
- "QZ_QR" , faster algorithm QR but with the more restricted perimeter.

The first two alternatives can be employed for the problems generalized and quadratic with or without hysteretic matrix/gyroscopic effect. Third is to be reserved for the dynamic problems, without

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damping, nor gyroscopic effect and not using Lagrange of blocking or connection. The method QZ will calculate all the modes associated with physical ddls (ddls not blocked and without Lagranges) and the usual parameter setting with the operator will make it possible to the user to make the sort of it (option "BANDAGES", "CENTER", "PLUS_PETITE").

3.8 Key word **MODE_RIGIDE**

Key word usable only with the method of Lanczos for a generalized modal problem. It makes it possible to detect and calculate as a preliminary, by an algebraic method the modes of body of rigid (modes associated with an eigenfrequency null) (cf [§5.5.4] [R5.01.01]). 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 eigenfrequencies calculated by the algorithm of Lanczos are not null but very close to zero.

3.9 Key word CALC_FREQ

◇ CALC_FREQ = _F (...

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

3.9.1 Operand OPTION

◇OPTION =

"TAPE"	One searches all the eigenfrequencies in a given tape. This tape is defined by the argument of <code>FREQ</code> : (f_1, f_2) . This option is not usable with a problem quadratic modal.
"CENTER"	One searches the <code>NMAX_FREQ</code> the eigenfrequencies closest to the frequency <code>F</code> (argument of key word <code>FREQ</code> : <code>F</code>).
"PLUS_PETITE" [DEFAULT]	One searches the <code>NMAX_FREQ</code> smaller eigenfrequencies.
"PLUS_GROSSE"	One searches the <code>NMAX_FREQ</code> greater eigenfrequencies. 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 <code>VERI_MODE</code> . Indeed, in the middle of the algorithm, before being converted into physical eigenfrequencies, the eigenvalues can be very small and very close.

See [§2.9] and [§4.4] [R5.01.01].

3.9.2 Operand APPROCHE

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

This key word defines the type of approach (real, imaginary or complex) for the choice of pseudo-produced scalar of the quadratic problem (cf [§5.5.2] [R5.01.02]). In general the value by default (reality) is valid.

This operand does not have a meaning that for the analysis of free vibrations of a damped structure.

3.9.3 Operand FREQ

◇FREQ = l_f

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

OPTION = "TAPE"	One expects two values (f_1, f_2) 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.

3.9.4 Operand AMOR_REDUIT

◇AMOR_REDUIT = l_a

Value of the reduced damping which makes it possible to define the eigenvalue complexes around which one seeks the closest eigenvalues.

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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.

3.9.5 Operand NMAX_FREQ

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

maximum Number of eigenfrequencies to calculating.

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

3.9.6 Operand DIM_SOUS_ESPACE

◇/ DIM_SOUS_ESPACE =des
/COEF_DIM_ESPACE =mse

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 [§4.3], [§5.5.2], [§6.5.3], [§7.3.1] [R5.01.01]) 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.

Note:

- If one uses the method of Sorensen (IRAM) and that $ndim - nf < 2$, of the data-processing requirements numérico - force to impose $ndim = nf + 2$.
- Into quadratic one works on a real problem of double size: $2 \times nf \quad 2 \times ndim$.

3.9.7 Operands SEUIL_FREQ, PREC_SHIFT and NMAX_ITER_SHIFT

◇PREC_SHIFT=ps (0.05) [DEFAULT]
◇SEUIL_FREQ=sf (0.01) [DEFAULT]
◇ NMAX_ITER_SHIFT=ns (3) [DEFAULT]

For three possible options "PLUS_PETITE", "TAPE" or "CENTER", one carries out a factorization LDL^T of the matrix $(A - (2\pi f_*)^2 B)$. f_* depends on the method used. If f_* is detected as being an eigenfrequency or being located near eigenfrequencies (loss of more than decimal *ndeci*=8 during the factorization of the matrixes), the frequency f_* is then modified (cf [§2.6] and [§2.9] [R5.01.01]):

$$f_*^- = f_* \times (1 - ps) \text{ or } f_*^+ = f_* \times (1 + ps)$$

If $(A - (2\pi f_*)^2 B)$ is not factorisable LDL^T and $(|f_*| \leq sf)$, the following modification is carried out: $f_*^- = -sf$. It is considered whereas f_* is associated with a mode of rigid body. The modification of this frequency makes it possible a priori to enter all the modes of rigid body. One does not carry out more *ns* modifications of the value f_* .

In the case of linear buckling, the transposition is immediate while replacing f_* (frequency of vibration) by λ_* (critical load), $(2\pi f_*)^2$ by λ_* and *sf* par. $(2\pi sf)^2$

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.

3.9.8 Operand STOP_BANDE_VIDE

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

"OUI" stops computation if no eigenfrequency 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.

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

3.10 Key word VERI_MODE

◇VERI_MODE = _F (...

Key word factor for the definition of the parameters of the checking of the eigen modes ([§2.9] [R5.01.01]).

3.10.1 Operand 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` is not checked.
By default the concept of output is not produced.

3.10.2 Operand SEUIL

◇SEUIL=r (1.10-6) [DEFAULT]

tolerance Level for the error norm relative of the mode to the top of which the mode is regarded as forgery.

The relative error norm of the mode is:

$$\frac{\|(\mathbf{A} - \lambda \mathbf{B})\mathbf{x}\|_2}{\|\mathbf{Ax}\|_2} \text{ for } \lambda \neq 0 \text{ the generalized problem and}$$

$$\frac{\|(\lambda^2 \mathbf{B} + \lambda \mathbf{C} - \mathbf{A})\mathbf{x}\|_2}{\|\mathbf{Ax}\|_2} \text{ the quadratic problem}$$

3.10.3 Operand 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 eigenfrequencies in the interval of search ([§2.5] [§2.6] [R5.01.01]).

3.10.4 Operand PREC_SHIFT

◇PREC_SHIFT=prs (0.05) [DEFAULT]

This parameter (which is a percentage) makes it possible to define an interval containing the calculated eigenfrequencies, for which the checking of Sturm type will be carried out ([§2.6] [R5.01.01]).

3.11 Operand INFO

◇INFO = 1 [DEFAULT]
/2

Indicates the level of printing in the message file .

- 1: Printing on the file "MESSAGE" of the eigenfrequencies, their modal position, reduced damping, the error norm a posteriori and certain useful parameters to follow the course of computation (cf [§5.2])
- 2: Printing rather reserved for the developers.

3.12 Operand TITER

◇TITER = Ti

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