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Operator `DYNA_NON_LINE`

1 Goal

To calculate the dynamic evolution of a structure whose material or geometry has a nonlinear behavior. They can be for example nonmaterial linearities (plasticity or of geometry (great displacements)) [R5.05.05]. The syntax of this order is very similar to that of the operator `STAT_NON_LINE` [U4.51.03].

The dynamic evolution is studied starting from an initial state, configuration of reference, which can be produced by a quasi-static analysis (operator `STAT_NON_LINE` [U4.51.03]) or former dynamics (operator `DYNA_NON_LINE`).

The dynamic evolution can be studied in several successive work, by a continuation as from one moment already calculated, if a database were defined in the profile of study of the user.

Product a concept of the type `evol_noli`.

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2   Syntax

```
dynanl [evol_noli] = DYNA_NON_LINE
(   ◊  reuse          =  dynanl,                    [evol_noli]
    ♦  MODEL          =  Mo,                        [model]
    ♦  CHAM_MATER     =  chmat,                     [cham_mater]
    ◊  MODE_STAT      =  modestat,                  [mode_meca]
    ◊  CARA_ELEM      =  carac,                     [cara_elem]
    ◊  MASS_DIAG      =  /'YES',
                        /'NOT',

    ◊  EXCIT          =_F (
            ◊  TYPE_CHARGE  = /'FIXE_CSTE',   [DEFECT]
                              /'SUIV',
                              /'DIDI',
            ◊  LOAD      = chi,           [char_meca]
                                          [char_cine_meca]
            ◊  /  FONC_MULT =  fi ,       [function]
               /  DEPL     =  depl,       [function]
                  QUICKLY      =  quickly,
[function]
                  ACCE     =  acce,       [function]
            ◊  MULT_APPUI  = /'NOT',      [DEFECT]
                            /'YES',
            ◊  DIRECTION   = (d1, d2, d3),   [l_R]
            ◊  NODE        = lno,         [l_noeud]
            ◊  GROUP_NO    = lgrno,       [l_gr_noeud]
                ),

    ◊  SOUS_STRUC      =_F ( to see the document [U4.51.03]),

    ◊  AMOR_RAYL_RIGI  =  /'TANGENT',              [DEFECT]
                         /'ELASTIC',

    ◊  AMOR_MODAL      =_F (
            ♦  MODE_MECA   =  mode,           [mode_meca]
            ♦  /AMOR_REDUIT =  l_amor,        [l_R]
               /LIST_AMOR   =  lisamor        [listr8]
            ◊  NB_MODE      = /nbmode,         [I]
                             /9999,           [DEFECT]
            ◊  REAC_VITE    = /'YES',          [DEFECT]
                             /'NOT',
                ),

    ♦  |  BEHAVIOR      =_F ( to see the document [U4.51.11]),

    ◊  ETAT_INIT        =_F ( to see the document [U4.51.03]
                |  QUICKLY         =  quickly,
[cham_no_DEPL_R]
                |  ACCE        =  acce,        [cham_no_DEPL_R]
                ),

    ♦  INCREMENT       =_F (see the document [U4.51.03])
    ◊  EXCIT_GENE      =_F (
            ◊  FONC_MULT    = fomult,     [fonction_sdaster]
            ♦  VECT_GENE    = vecgen,     [vect_asse_gene]
```

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```
                    ),

        ◊    NEWTON         =_F ( to see the document [U4.51.03]),

        ◊    RECH_LINEAIRE   =_F ( to see the document [U4.51.03]),

        ◊    SOLVEUR        =  _F ( to see the document [U4.50.01] ),

        ◊    CONVERGENCE  =  _F ( to see the document [U4.51.03]),

        ◊    MODE_VIBR =_F (
             ◊   NB_FREQ         = /3,                    [DEFECT]
                                   /nbfreq,               [I]
             ◊   MATR_RIGI       = / 'ELASTIC',           [DEFECT]
                                   /'TANGENT',
                                   /'SECANT',
             ◊   BAND        =     intba ,                [listr8]
              ◊  /LIST_INST   =  list_r8,                 [listr8]
                 /INST        =  l_r8,                    [R]
                 /PAS_CALC    =  npas,                    [I]
             ◊   PRECISION       = /1.E-6,                [DEFECT]
                                   /prec,                 [R]
             ◊   CRITERION       = /'RELATIVE',           [DEFECT]
                                   /'ABSOLUTE',
             ),

        ◊   CRIT_STAB   = _F ( to see the document [U4.51.03]),
        ◊   ENERGY    = _F ()

        ◊   FILING   = _F ( to see the document [U4.51.03]),

        ♦   SCHEMA_TEMPS =_F (
                        ♦ DIAGRAM   =  /  'NEWMARK',
                                      /  'HHT',
                                      /  ' THETA_METHODE ' ,
                                      /  'KRENK ' ,
                                      /  'DIFF_CENT',
                                      /  'TCHAMWA',
                        ◊    COEF_MASS_SHIFT = /  0. ,         [DEFECT]
                                              /  coeff,    [R]
{If DIAGRAM      =   'NEWMARK'
                        ◊    BETA  =  /  0.25,             [DEFECT]
                                     /  beta,             [R]
                        ◊    GAMMA  =  /  0.5 ,            [DEFECT]
                                      /  gamm,            [R]
}

{If DIAGRAM      =   'HHT'
                        ◊    ALPHA  =  /  -0.3,            [DEFECT]
                                      /  alph,            [R]
                        ◊    MODI_EQUI =    /  'YES',
                                           /  'NOT',      [DEFECT]
}

{If DIAGRAM      =   'THETA_METHODE'
                        ◊    THETA  =  /  1. ,            [DEFECT]
                                      /  theta,          [R]
}

{If DIAGRAM      =   'KRENK'
                        ◊    KAPPA  =  /  1. ,            [DEFECT]
```

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```
                                           /   kappa,              [R]
          }

          {If DIAGRAM    =   'TCHAMWA'
                          ◊      PHI   = /   1.05               [DEFECT]
                                        /   phi,               [R]
          }

          {If DIAGRAM    =   /   'NEWMARK',
                            /   'HHT',
                            /   'THETA_METHODE',
                            /   'KRENK',
                            ♦   FORMULATION  = /   'DISPLACEMENT',
                                             /   'SPEED',
                                             /   'ACCELERATION',
          }

          {If DIAGRAM    =   /   'DIFF_CENT',
                            /   'TCHAMWA',
                            ♦   FORMULATION  =     'ACCELERATION',
                            ◊    STOP_CFL    = /   'YES',         [DEFECT]
                                              /   'NOT',
          }, ),

               ◊   OBSERVATION  = _F  ( to see the document [U4.51.03]),
               ◊   POSTING   = _F   ( to see the document [U4.51.03]),

               ◊   PROJ_MODAL = F  (
                            ♦   MODE_MECA =  mode,            [mode_meca]
                            ◊   NB_MODE     = /   nbmode,     [I]
                                            /   9999,        [DEFECT]
                            ◊   /MASS_GENE   =  massgen       [matr_asse_gene_R]
                                 RIGI_GENE   =  rigigen       [matr_asse_gene_R]
                                /  AMOR_GENE =  amorgen       [matr_asse_gene_R]
                            ◊      DEPL_INIT_GENE = deplgen,    [ vect_asse_gene ]
                            ◊      VITE_INIT_GENE = vitegen,    [ vect_asse_gene ]
                            ◊      ACCE_INIT_GENE = accegen,    [ vect_asse_gene ]
                       ),

               ◊   INFORMATION    =    / 1,                          [DEFECT]
                           / 2,

               ◊   TITLE = tx   ,                           [KN]    )
```

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3   Operands

3.1   Operands MODEL/CHAM_MATER/CARA_ELEM

These operands have the same meaning as danS the document [U4.51.03].

3.2   Operands MODE_STAT/MASS_DIAG

◊   MODE_STAT = modestat

Name of the static mode necessary in the case of a seismic calculation with excitations multi-supports [R4.05.01].

◊   MASS_DIAG = / 'YES',
              / 'NOT',

Option to be used with a diagram in time clarifies [bib2] and which makes it possible to solve with a matrix of lumpée mass (diagonalized). This option is not available for all the types of elements, in particular the discrete ones (in this case, it is necessary to solve with the matrix of consistent mass). Into implicit it is not possible to use a lumpée matrix (emission of a fatal error if the user is in this case)

3.3   Keyword EXCIT

◊   EXCIT =_F

This keyword factor makes it possible to describe with each occurrence a load (requests and boundary conditions), and possibly a multiplying coefficient and/or a kind of load.

The operands have the same meaning as danS the document [U4.51.03] but there are some specificities related to dynamics.

Notice important for the diagrams in time:

If one imposes boundary conditions in displacement which evolves in the course of time, it is necessary to take account of the primal unknown factor of the diagram used. These conditions in fact are imposed in acceleration into explicit (because it is the primal unknown factor). That means that one must enter DYNA_NON_LINE the derivative second of the signal in displacement which one wants to impose. This evolution of imposed displacement must thus be derivable at least twice in time. In the same way for the theta-diagram of speed, the primal unknown factor is speed and one must enter DYNA_NON_LINE the derivative first of the signal in displacement which one wants to impose.

3.3.1   Operands LOAD/FONC_MULT

♦   LOAD = ch_i
◊   FONC_MULT = f_i

The operands have the same meaning as danS the document [U4.51.03].

3.3.2   Operand TYPE_CHARGE

◊   TYPE_CHARGE =/'FIXE_CSTE' ,   [DEFECT]
              / 'SUIV',
              / 'DIDI',

The operand has the same meaning as danS the document [U4.51.03], except that a loading cannot be controlled in dynamics, and thus tchi cannot be FIXE_PILO.

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3.3.3 Operands MULT_APPUI/ACCE/QUICKLY/DEPL/DIRECTION/NODE/GROUP_NO

◊   MULT_APPUI= /'NOT',   [DEFECT]
                /'YES',
♦   ACCE   = ac,   [function]
♦   QUICKLY   = VI,   [function]
♦   DEPL   = dp,   [function]
◊   DIRECTION = (dx, Dy, dz, drx, dry Martini, drz),   [l_R]
◊   /NOEUD   = lno,   [l_noeud]
    /GROUP _ NO = lgrno,   [l_groupe_no]

In the case of an excitation multi-supports (MULT_APPUI= 'YES'), the other operands have exactly the same meaning as in the keyword factor EXCIT of the operator DYNA_TRAN_MODAL [U4.53.21]. In this case, fields 'DEPL', 'QUICKLY', 'ACCE' correspond respectively to displacements, speeds and accelerations of the movement relative compared to the movement of training multi-supports. New fields 'DEPL_ABSOLU', 'VITE_ABSOLU', 'ACCE_ABSOLU' are then created and respectively correspond at displacements, the speeds and accelerations of the absolute movement, summons movement of training multi-supports and relative movement compared to this movement of training multi-supports.

3.4 Keyword CONTACT

♦   CONTACT = contact

This simple keyword makes it possible to activate the resolution of contact-friction or the taking into account of a unilateral connection. contact is a concept resulting from the operator DEFI_CONTACT [U4.44.11].
The operand has the same meaning as danS the document [U4.51.03].

3.5 Keyword SOUS_STRUC

◊   SOUS_STRUC=_F

This keyword factor makes it possible to specify which are the loadings to be used for under - static structures which then are obligatorily part of the model.
The operand has the same meaning as danS the document [U4.51.03].

3.6 Keyword BEHAVIOR

The syntax of these keywords common to several orders is described in the document [U4.51.11]. All relations of behavior supported by STAT_NON_LINE are available also in DYNA_NON_LINE, provided that the calculation of the matrix of mass of the elements concerned is envisaged.

3.7 Keyword ETAT_INIT

◊   ETAT_INIT =_F

Under this keyword the initial conditions of the problem are defined. Operands of the keyword ETAT_INIT have the same meaning as in the document [U4.51.03].

In dynamics, one can define in more the fields initial speed and acceleration.

♦   / |QUICKLY = quickly
    / | ACCE = acce

If keywords EVOL_NOLI, DEPL, and QUICKLY are absent, one supposes that the initial state is with worthless displacements, speeds and constraints, and one calculates accelerations corresponding to the loading at the moment instini defined by the operand INST.

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3.8 Keyword INCREMENT

♦ INCREMENT =_F

The list of the moments of calculation defines. Operands of the keyword INCREMENT have the same meaning as danS the document [U4.51.03].

3.9 Keyword NEWTON

◊ NEWTON =_F

Specify the characteristics of the method of resolution of the nonlinear incremental problem (method of Newton-Raphson). Operands of the keyword NEWTON have the same meaning as in the document [U4.51.03].

3.10 Keyword RECH_LINEAIRE

◊ RECH_LINEAIRE =_F (
◊   METHOD = /'CORD'   [DEFECT]
              /'MIXED')

Allows to activate linear research. Operands of the keyword RECH_LINEAIRE have the same meaning as in the document [U4.51.03], except that method PILOTING do not exist.

3.11 Keyword SOLVEUR

◊ SOLVEUR =_F
The syntax of this keyword common to several orders is described in the document [U4.50.01].

3.12 Keyword CONVERGENCE

◊ CONVERGENCE =_F

This keyword describes the parameters making it possible to appreciate the convergence of the method of NEWTON used to solve the nonlinear mechanical problem. Operands of the keyword CONVERGENCE have the same meaning as in the document [U4.51.03].

3.13 Keyword FILING

◊ FILING =_F

Allows to file or certain results at all or certain moments of calculation.
In the absence of this keyword all the steps of time are filed, including the moments of calculations lately created by automatic recutting of the step of time. Operands of the keyword FILING have the same meaning as in document [U4.51.03], except for the keyword CHAM_EXCLU.

3.13.1 Operand CHAM_EXCLU

◊ CHAM_EXCLU   = |' DEPL'
                     |' VITE'
                     |' ACCE'
                     |' SIEF_ELGA'
                     |' VARI_ELGA'

Allows to specify the fields which will not be filed, except with the last step of time.

3.14 Keyword AMOR_RAYL_RIGI

◊ AMOR_RAYL_RIGI = /'TANGENT',   [DEFECT]
                     /'ELASTIC'

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This keyword makes it possible to specify the matrix of stiffness K who will be used to build the damping of Rayleigh $C = \alpha . K + \beta . M$.

With the value by default ('TANGENT'), the matrix K will be the same one as that which is used for the calculation of the internal efforts. By choosing the value 'ELASTIC', one forces the calculation of the damping of Rayleigh with the elastic matrix of stiffness.

For the lenitive laws or of type GLRC one advises to use the elastic matrix.

3.15 Keyword AMOR_MODAL

◊   AMOR_MODAL   = _F

This keyword makes it possible to take into account a damping equivalent to modal damping broken up on a basis of modes precalculated in the form of concept of the type mode_meca. This damping is taken overall into account in the dynamic equilibrium equation like a correct force with the second member $-C . \dot{X}$.

3.15.1 Operands MODE_MECA / AMOR_REDUIT / LIST_AMOR / NB_MODE

♦   MODE_MECA   =   mode
♦   /   AMOR_REDUIT =   l_amor,
     /   LIST_AMOR   =   lisamor
◊   NB_MODE   =   nbmode

The concept mode of the type mode_meca (entered by the operand MODE_MECA) represent the base of modes precalculated on which one breaks up modal damping. This base must imperatively have the same profile of classification as that of the dynamic system defined by the parameters of the keyword SOLVEUR [§3.11]. It is possible to truncate the modal base with a number of modes defined by NB_MODE. Failing this, one takes all the modes of the modal base.

Modal depreciation in reduced form is given by a list of realities of which the number of terms is lower or equal to the number of modes taken into account. If the number of terms of the list is strictly lower, one extends this list with the value of his last term until its size reaches the number of calculated modes.

3.15.2 Operand REAC_VITE

◊   REAC_VITE=   /'YES',   [DEFECT]
                  /'NOT',

If its value is 'YES', one modifies the correct force of modal damping to each internal iteration of Newton defined in the keyword NEWTON [§9].

If its value is 'NOT', one updates this term only to the beginning of each step of time.

3.16 Description of the diagram of integration in time [bib2] [R5.05.05]

♦   SCHEMA_TEMPS = _F ()
◊   STOP_CFL =   /'YES',   [DEFECT]
                    /'NOT',
◊   FORMULATION= /'DISPLACEMENT',
                   /'SPEED',
                   /'ACCELERATION',

One can is to use an implicit method of NEWMARK (keyword DIAGRAM= 'NEWMARK' or modified average acceleration: DIAGRAM= 'HHT' with MODI_EQUI = 'NOT'), of HILBER-HUGHES-TAYLOR (SCHEMA=' HHT' with MODI_EQUI = 'YES') or one THETA_METHODE or, finally, the diagram of KRENK.

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With an implicit scheme, the resolutions in displacement, speed or acceleration are currently available (keyword FORMULATION = 'DISPLACEMENT', 'SPEED' or 'ACCELERATION').

Conversely, one can choose an explicit method of centered differences type (keyword SCHEMA='DIFF_CENT') or a dissipative diagram of type TCHAMWA (keyword SCHEMA='TCHAMWA'). With an explicit diagram, one can solve only in acceleration (keyword FORMULATION = 'ACCELERATION').

The explicit diagrams being conditionally stable, it can be useful to check if the step of time given as starter of calculation observes well the stability condition (condition CFL). If STOP_CFL = 'YES' (defect), then if the list of moments provided by the user comprises one or more step of times higher than the stability condition, calculation stops in fatal error. If STOP_CFL = 'NOT', one emits an alarm and continues calculation.
In all the cases, the critical step of time is given in the file of messages for information.
The calculation of the CFL is not programmed for all the elements (in particular the discrete elements are ignored.); the CFL estimated by *Code_Aster* can thus be larger (less penalizing) that the real CFL, with the risks of brutal divergence which results from this.
Into explicit, it is also recommended to use a matrix of lumpée mass (diagonalized): what one can obtain with the keyword MASS_DIAG = 'YES' [§7].

Note:
- *The choice MASS_DIAG=' NON' is disadvised with the hulls DKT.*
- *With the elements DKT/DKTG it is necessary to specify in AFFE_CARA_ELEM , under the keyword factor HULL , the simple keyword INER_ROTA = 'YES' . If not mass stamps it is singular ET the explicit diagram is unusable.*
- *Into explicit, one disadvises the use of the quadratic finite elements (which can generate parasitic oscillations on the fields solutions).*
- *For the multi-step diagrams (Newmark with MODI_EQUI=' OUI' and theta-diagram), it is necessary to recompute the interior efforts at the previous moment. This operating process is problematic at the first moment of a resumption of calculation. Indeed, if there are variables of orders (which thus depend on the moment of calculation), it is necessary to recover the value of the previous moment. It is not always possible, in particular if one is not in reuse and if ETAT_INIT is done starting from individual fields (not use of the keyword ETAT_INIT/EVOL_NOLI). In this case, one does not calculate this contribution to the preceding step, which can possibly modify the convergence of the algorithm slightly.*

3.16.1 Case DIAGRAM = 'NEWMARK'

```
◊   BETA      =  /0.25,                        [DEFECT]
               /beta,                         [R]
◊   GAMMA     =  /0.5 ,                        [DEFECT]
               /gamm,                         [R]
```

The method of integration in time is that of NEWMARK, with the values given of the parameters beta and gamm.
When one does not specify nor beta, nor gamm, there is the method known as "regulates trapezoid" ($beta=0.25$; $gamm=0.5$) who, into linear, is unconditionally stable and does not bring any dissipation parasitizes (*i.e.* digital damping), but which, into nonlinear, can be unstable [bib1] [bib2].

3.16.2 Case DIAGRAM = 'HHT'

```
◊   ALPHA     =  /-0.3,                        [DEFECT]
               /alph,                         [R]
◊   MODI_EQUI =  /'YES',
               /'NOT',                        [DEFECT]
```

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For MODI_EQUI = 'NOT' (value by default), the method of integration in time (implicit diagram of integration) is that of the modified average acceleration (of the family of Newmark) ([bib1], [bib2]), with the negative value of alph data. More |alph| is large, more the digital damping brought by calculation is important. But this dissipation is sometimes necessary, into nonlinear, to ensure stability (unless assigning a damping by material to the structure).

For MODI_EQUI = 'YES', the method of integration in time (implicit diagram of integration) is that of HILBER - HUGHES - TAYLOR (HHT or $\alpha-\text{méthode}$) [bib2], with the negative value of alph data. More |alph| is large, more the digital damping brought by calculation is important. By report with the preceding diagram (MODI_EQUI = 'NOT') of modified average acceleration, induced digital damping is more "selective": it is weaker with low and intermediate frequency (asymptotically no one at worthless frequency) and it will grow more quickly when the frequency becomes large.

This second diagram is based on the first with, moreover, one modification of the equilibrium equation (one shifts in time the interior and external efforts) [bib2].

3.16.3 Case DIAGRAM = 'THETA_METHODE'

◊   THETA   =   /1. ,   [DEFECT]
                  /theta,   [R]

The diagram of integration in time is an implicit theta-diagram of order one, of speed. In the case of use with loads of contact, one must also call on the method CONTINUOUS (AFFE_CHAR_MECA/CONTACT/METHOD = 'CONTINUE') and the formulation of speed (FORMULATION = 'SPEED').

theta must be ranging between 0.5 and 1: 0.5 corresponds to a minimum of digital dissipation, 1 corresponds to a maximum of digital dissipation. theta = 1 makes it possible to find the diagram of Euler. This diagram is also usable with a formulation in displacement.

3.16.4 Case DIAGRAM = 'KRENK'

◊   KAPPA   =   /1. ,   [DEFECT]
                  /kappa,   [R]

It of integration in times of Krenk is implicit, of a nature 1 and dissipative. Its use is thus recommended, just like the theta-diagram, for the irregular problems like the shocks.

Digital dissipation is controlled by the parameter **kappa**, which must be equal to or higher than 1. If it is worth 1, then the diagram will not bring dissipation. More **kappa** will be large, more dissipation will be high.

3.16.5 Case DIAGRAM = 'DIFF_CENT'

The diagram of the centered differences is an explicit diagram of order two of the family of Newmark, parameters BETA = 0 and GAMMA = 0.5. It is about a diagram to a step which does not present digital dissipation.

3.16.6 Case DIAGRAM = 'TCHAMWA'

◊   PHI   =   /1.05,   [DEFECT]
                  /phi,   [R]

An alternative to the diagrams of the centered differences is the diagram developed by Bertrand Tchamwa and Christian Wielgosz.

This explicit diagram has several interesting characteristics. It is not a derivative of Newmark, and the variation of its parameter PHI a controllable digital dissipation of the high frequencies allows. When it is worth 1, dissipation is worthless. Not too much not to degrade the condition of Current and to preserve properties of stability comparable to the diagram of the centered differences, it is recommended not to choose one PHI superior at 1.10. 1.05 is the selected value by default.

3.16.7 Operand COEF_MASS_SHIFT

◊   COEF_MASS_SHIFT = /0.   [DEFECT]
                        /coef

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The data of the coefficient `coeff` allows to carry out a shift of the matrix of mass M who becomes:
$M' = M + coef\,K$
The value of this coefficient, by default worthless, must be nonworthless to be able to reverse in dynamics with diagram clarifies the matrix of mass when this one has worthless terms for certain specific degrees of freedom, for example the pressure for the elements of modeling `HM`.
The entry of this coefficient also makes it possible to strongly improve convergence in dynamics with implicit scheme in this same type of modeling by imposing a cut-off frequency inversely proportional to the value of `coeff` (at the cost of a light distortion of the whole of the Eigen frequencies of the system)

3.17 Keyword CRIT_STAB

◊ CRIT_STAB = _F

This keyword makes it possible to start calculation, at the end of each increment of time, of a criterion of stability, identical to what is proposed in `STAT_NON_LINE`. This criterion is useful to detect, during the loading, the point from which one loses stability (by buckling for example). It is not about a criterion of stability to the dynamic direction (negative damping). Operands of the keyword `CRIT_STAB` have the same meaning as in the document [U4.51.03].
It is however advisable to announce that the use of `CRIT_STAB` on models fluid-structure coupled (formulation (u, p, ϕ), *cf.* documentation [R4.02.02], which is available with `DYNA_NON_LINE` but not `STAT_NON_LINE`) oblige to exclude the degrees of fluid freedom because the matrix from total assembled rigidity is singular for these degrees of freedom. For that, the keyword should be combined `DDL_EXCLUS` (by excluding all the degrees of freedom specific to the fluid elements, like 'CLOSE', 'PHI' and, in the cases with free surface, 'DH') and `MODI_RIGI = 'YES'`. More details are given in documentations [U4.51.03], [U2.06.11] and [U2.08.04].

3.18 Keyword MODE_VIBR

```
◊   MODE_VIBR    = _F (
        ◊    NB_FREQ         =  /3,                [DEFECT]
                               /nbfreq,            [I]
        ◊    MATR_RIGI       =  /'ELASTIC',        [DEFECT]
                               /'TANGENT',
                               /'SECANT',
        ◊    BAND            =  intba,             [listr8]
         ◊  /LIST_INST       =  list_r8,           [listr8]
            /INST            =  l_r8,              [R]
            /PAS_CALC        =  npas,              [I]
        ◊    PRECISION       =  /1.e-6             [DEFECT]
                               /prec
        ◊    CRITERION       =  /'RELATIVE',       [DEFECT]
                                /'ABSOLUTE',
            ),
```

This keyword makes it possible to start calculation, at the end of each increment of time, of a search for vibratory clean modes.
This criterion is useful to follow, during transitory calculation, the evolution of the vibratory answer of the nonlinear structure.

This criterion is calculated in the following way: at the end of a step of time, one solves $det(K - \omega^2.M) = 0$. K can either be the matrix of elastic stiffness, or the coherent tangent matrix at the moment running, or the secant matrix. M is the matrix of mass. This modal analysis is authorized only for the symmetrical matrices (mass and stiffness).

The keyword `NB_FREQ` (3 by defaults) the number of Eigen frequencies indicates to calculate.

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One stores the clean mode the corresponding to smallest Eigen frequency in S.D. RESULT, under the name DEPL_VIBR. This clean mode can be extracted and visualized (like a field of displacements or a classical clean mode). It is standardized with 1 on the largest component of displacement. All the calculated Eigen frequencies are given in the file .mess.

The keyword BAND allows to specify on which waveband one wants to make the search for Eigen frequencies.

The moments for which one wants to do a calculation of oscillatory mode are given by a list of moments LIST_INST or INST (list_r8 or l_r8) or by a frequency PAS_CALC (all them *npas* time).

In the absence of these keywords the vibratory modal analysis is carried out with all the steps of time. Keywords PRECISION and CRITERION permettent to select the moments, *cf.* [U4.71.00].

3.19 Operand ENERGY

◊   ENERGY = _F ()

This keyword makes it possible to activate the calculation of the assessment of energy, its posting in the course of calculation and its storage in the table of name PARA_CALC. The assessment of energy can be extracted from this table using the order RECU_TABLE [U4.71.02].

3.20 Operand PROJ_MODAL

◊   PROJ_MODAL =_F

This keyword makes it possible to calculate on a modal basis (or Ritz) calculated beforehand. It is to be used with a diagram of integration in explicit time.

3.20.1 Operands MODE_MECA, NB_MODE

♦   MODE_MECA   =   mode,   [mode_meca]

◊   NB_MODE   = /nbmode,   [I]
                    /9999,   [DEFECT]

One specifies the base to be used (MODE_MECA) and the number of modes (NB_MODE).

Notice important:

The modal base must be based on a coherent classification with that of the calculated evolution (cf [§10]): even profile of classification.

3.20.2 Operands MASS_GENE , RIGI_GENE , AMOR_GENE

◊   /   MASS_GENE = massgen,   [matr_asse_gene_R]
        RIGI_GENE = rigigen,   [matr_asse_gene_R]
        AMOR_GENE = amorgen,   [matr_asse_gene_R]

These operands are used together if one wants to dynamically condense part of the model to the linear behavior, while not calculating strictly by DYNA_NON_LINE that fields with the behavior non-inéaire. This, in order to reduce the size of the model of calculation. In this case, it is necessary to calculate a modal base of Ritz on the whole of the fields: the nonlinear field modelled for calculation which calls on DYNA_NON_LINE and other dynamically condensed linear fields. This base must be orthogonalized compared to the mass and with a linear rigidity of the whole of the fields. It must simply be representative of the movements activating the whole of the fields. On the other hand, one will not inform behind MODE_MECA that modes obtained by reduction of the base of Ritz to the model

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of calculation treated by DYNA_NON_LINE. An example of calculation is provided by the case test SDNV107A [V5.03.107].

The operand MASS_GENE the projection of the matrix makes it possible to enter masses of the whole of the fields on the basis of Ritz with a diagonal storage. The operand RIGI_GENE makes it possible to enter the projection of the matrix rigidity of the linear fields condensed only on the basis of Ritz with a full storage. The operand AMOR_GENE the projection of a matrix of damping (if it exists) makes it possible to possibly enter linear fields condensed only on the basis of Ritz with a full storage.

3.20.3 Operands DEPL_INIT_GENE , VITE_INIT_GENE , ACCE_INIT_GENE

◊   DEPL_INIT_GENE = deplgen,   [vect_asse_gene]
◊   VITE_INIT_GENE = vitegen,   [vect_asse_gene]
◊   ACCE_INIT_GENE = accegen,   [vect_asse_gene]

These operands are associated with the use of the operands MASS_GENE, RIGI_GENE and possibly AMOR_GENE in the keyword PROJ_MODAL. It are used to introduce a generalized vector resulting from projection by **PROJ_VECT_BASE** (TYPE='DEPL') of a field displacement or speed or acceleration of the complete model (including the field with the linear behavior) on the basis of this modal complete model. This generalized vector will serve as initial condition of the evolution of the coordinates generalized of calculation on the scale model with the nonlinear field. It will then be necessary also to inform the operands of the keyword ETAT_INIT with corresponding fields displacement, speed, acceleration, constraint, variable intern scale model. An example of calculation is provided by the case test SDNV107C [V5.03.107].

3.21 Keyword EXCIT_GENE

◊   EXCIT_GENE =_F (
    ◊   FONC_MULT = fomult,   [fonction_sdaster]
    ♦   VECT_GENE = vecgen,   [vect_asse_gene]
)

This keyword répétable is associated with the use of the operands MASS_GENE, RIGI_GENE and possibly AMOR_GENE in the keyword PROJ_MODAL. It is used to introduce the forces applied to fields of linear behavior condensed dynamically and not modelled into calculation which calls on a diagram of integration in explicit time. These forces are projected on the basis of Ritz calculated on the whole of the fields.

VECT_GENE is used to inform the vectors of force projected on the basis of Ritz. FONC_MULT is used to inform the multiplying function depending on time associated with each vector within an occurrence with the keyword EXCIT_GENE.

3.22 Operand INFORMATION

◊   INFORMATION =inf

Allows to carry out in the file message various intermediate impressions.
Other impressions are made systematically during nonlinear calculation, independently of the value assigned to the keyword INFORMATION : they are the impressions of the residues and the relative increments of displacement during iterations of Newton.
Attention, the files .mess can become very important with INFORMATION = 2.

3.23 Operand TITLE

◊   TITLE = tx

tx is the title of calculation. It will be printed at the top of the results. See [U4.03.01].

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4 Example: movement of a pendulum of great amplitude

```
#   Simple TITLE Pendulum in great oscillation
#
#   PENDULUM CONSTITUTES Of an ELEMENT OF CABLE (test SDNL100A).
#
RESU=DYNA_NON_LINE (MODELE=MO, CHAM_MATER=CHMAT, CARA_ELEM=CARA,
                    EXCIT= (_F (  LOAD = CHA1),
                            _F (  LOAD = CHA2)),
                    INCREMENT=_F (INST_INIT = 0. , LIST_INST = L_INST1),
                    ARCHIVAGE=_F (LIST_INST = L_INST2),
                    SCHEMA_TEMPS=_F (SCHEMA=' NEWMARK',
                                      FORMULATION=' DEPLACEMENT'),
                    COMPORTEMENT=_F (RELATION = 'CABLE',
                                DEFORMATION = 'GREEN'),
                    CONVERGENCE=_F (RESI_GLOB_RELA = 1.E-6,
                                    ITER_GLOB_MAXI = 100),
                    NEWTON=_F (REAC_ITER = 1)
                      )
END ()
```

- the load cha1 impose on node 1 to remain fixed and with node 2 to move in the vertical plan XZ,
- the load cha2 is gravity,
- the order DYNA_NON_LINE specify that:
  - the method of integration of time will be that of 'NEWMARK', "rule of the trapezoid" (also called average acceleration), because it has no argument there under 'NEWMARK',
  - the initial state, at moment 0, is with null displacement, i.e. displacements will be evaluated starting from the initial position, and at worthless speed,
  - iterative calculation will continue as much as the relative residue will be $> 10^{-2}$, but the number of the iterations will be limited to 100,
  - finally the tangent matrix of the linear system to solve will be revalued with each iteration (by default since the keyword NEWTON is absent).