Operator DYNA_VIBRA

1 Goal

DYNA_VIBRA allows to carry out calculation of a transitory or harmonic answer on a linear model on physical basis or modal basis. It can also treat the non-linearities located for calculations of transitory answer on modal basis.

The produced concept depends on the type of calculation carried out (tran_gene, dyna_trans, harm_gene, dyna_harmo or acou_harmo).

2 Syntax

```
nom_concept [dyna_vibra_prod] = DYNA_VIBRA (

      ◊  reuse =   nom_concept,
      ♦  BASE_CALCUL = ( | 'PHYS',
                         | 'GENE',
                       ),
      ♦  TYPE_CALCUL = ( | 'TRAN',
                         | 'HARM',
                       ),
# Keywords concerning the setting in data if harmonic or transitory calculation on physical basis :
      ◊  MODEL   = Mo,                                  [model]
      ◊  CHAM_MATER = chmat,                            [cham_mater]
      ◊  CARA_ELEM  = carac,                            [cara_elem]

# Keywords informing the assembled matrices :
      ♦  MATR_MASS =         my ,                       [matr_asse_gene_R]
                                                        [matr_asse_depl_R]
                                                        [matr_asse_pres_C]

      ♦  MATR_RIGI =         laughed   ,
   [matr_asse_gene_R]
                                                        [matr_asse_depl_R]
                                                        [matr_asse_pres_C]
                                                        [matr_asse_depl_C]
                                                        [matr_asse_gene_C]

      ◊  MATR_AMOR =         amndt  ,
   [matr_asse_gene_R]
                                                        [matr_asse_depl_R]
                                                        [matr_asse_pres_C]

      ◊  MATR_IMPE_PHI =  imp,                          [matr_asse_DEPL_R]
                                                        [matr_asse_GENE_R]

      ◊  BASE_ELAS_FLU =  melasflu,                     [melasflu]
      ◊  NUME_VITE_FLU =  nume_vite,                    [I]
         # if BASE_ELAS_FLU:
            ♦  TRAITEMENT_NONL =   'IMPLICIT',
         # if not:
            ♦  TRAITEMENT_NONL =   /'IMPLICIT',
                                   /'CLARIFIES'         [DEFECT]

# if harmonic calculation with D-returning concept:
      ◊   RESULT   =  harm,                             [dyna_harmo]
                                                        [harm_gene]
# introduction of modal damping:
      ◊  AMOR_MODAL = _F (
                        ◊  AMOR_REDUIT =       ,       [l_R]
                        ◊  LIST_AMOR   =    l_amor ,   [listr8]
                         # so transitory on physical basis
                        ♦  MODE_MECA   =    mode,      [mode_meca]
                        ◊  NB_MODE     =    nbmode,    [I]
                        ),
# parameters for harmonic calculation:
      ♦  /  FREQ                  =  lf,                [l_R]
         /  LIST_FREQ             =  cf,                [listr8]
```

```
        ◊  /  TOUT_CHAM              =  'YES',          [DEFECT]
           /  NOM_CHAM               =  |'DEPL',
                                        |'QUICKLY',
                                        |'ACCE',

# Operands specific to the taking into account of a transient speed
  for the rotors (number of revolutions variable)
        ◊  VITESSE_VARIABLE = 'NOT',                    [DEFECT]
                            / 'YES',
           # if VITESSE_VARIABLE == 'YES':
              ♦  VITE_ROTA =  vrota,                    [function]
              ♦  MATR_GYRO =  gyro,                     [matr_asse_gene_R]
              ◊  ACCE_ROTA =  arota,                    [function]
              ◊  MATR_RIGY =  gyro,                     [matr_asse_gene_R]
           # if VITESSE_VARIABLE == 'NOT':
              ◊  VITE_ROTA =  / 0.0,                    [DEFECT]
                              / vrota,                  [R]

# parameters of the diagrams of integration
        ◊ SCHEMA_TEMPS =_F (
                          ♦ DIAGRAM =  | 'NEWMARK',
                                       | 'WILSON',
                                       | 'DEVOGE',
                                       | 'ADAPT_ORDRE1',
                                       | 'ADAPT_ORDRE2',
                                       | 'DIFF_CENTRE',    [DEFECT]
                                       | 'ITMI',
                                       | 'RUNGE_KUTTA_54',
                                       | 'RUNGE_KUTTA_32',

# Keywords only associated with the diagram 'NEWMARK':
                          ◊ BETA    =/0.25,               [DEFECT]
                                     /beta,               [R]
                          ◊ GAMMA   =/0.5,                [DEFECT]
                                     /gamma,              [R]
# Keyword only associated with the diagram 'WILSON':
                          ◊ THETA   =/1.4,                [DEFECT]
                                     /th,                 [R]

# Associated keywords with all them diagrams adaptive :
                          ◊  NOT_MAXIMUM =       dtmax,   [R]
                          ◊  PAS_MINIS =         dtmin,   [R]
                          ◊  NMAX_ITER_NOT =  /  16,      [DEFECT]
                                              /  NR,      [I]

# Associated keywords with the diagrams 'RUNGE_KUTTA_*' and 'DEVOGE':
                          ◊ TOLERANCE  =/1.E-5,           [DEFECT]
                                        /tol,             [R]
                          ◊ ALPHA      =/0. ,             [DEFECT]
                                        /alpha,           [R]

# Keywords only associated with the diagrams 'ADAPT_ORDRE*' :
                          ◊  QUICKLY_MIN =    / 'NORM',   [DEFECT]
                                              / 'MAXIMUM',
                          ◊  COEFF_MULT_NOT = / 1.1  ,    [DEFECT]
                                              / cmp  ,    [R]
                          ◊  COEFF_DIVI_PAS = / 1.33333334,[DEFECT]
                                              /  cdp,     [R]
                          ◊  NOT_LIMI_RELA =  /  1.E-6,   [DEFECT]
                                              /  per,     [R]
```

```
                        ◊  NB_POIN_PERIOD = 50,        [DEFECT]
                                          /  NR,       [I]

                ),

      ♦   INCREMENT =_F ( ♦  /  LIST_INST = litps,     [listr8]
                             ◊  /  INST_FIN= tf,       [R]
                                /  NUME_FIN= nufin,    [I]
                             /  NOT = dt,              [R]
                             ◊  INST_INIT  = Ti,       [R]
                             ♦  INST_FIN= tf,          [R]

                        ◊  VERI_NOT =   / 'YES',       [DEFECT]
                                        / 'NOT',
                ),

      ◊ ETAT_INIT = _F ( ♦  /  RESULT = LMBO,          [tran_gene]
                              ◊ / NUME_ORDR E =  No,   [I]
                                / INST_INIT =   to,    [R]
                                  ◊ CRITERE= /'RELATIVE', [DEFECT]
                                             /'ABSOLUTE',
                                  # If 'RELATIVE' == CRITERION
                                  ◊ PRECISION =  / 1.E-06, [DEFECT]
                                                 / prec,   [R]
                                  # If 'ABSOLUTE' == CRITERION
                                  ♦ PRECISION = prec,      [R]

                             /  ◊  DEPL = C,             [vect_asse_gene]
                                                         [cham_no]
                                ◊  QUICKLY = vo,
[vect_asse_gene]
                                                         [cham_no]
                                 # on physical basis
                                ◊  ACCE = acc,           [cham_no]
                ),
      ◊ EXCIT =   _F (  ◊  / VECT_ASSE      =  v,          [cham_no]
                           / VECT_ASSE_GENE =  v,          [vect_asse_gene]
                           / LOAD =  chi,                [char_meca]
                        ◊  /  FONC_MULT =  F,            [function]
                                                         [tablecloth]
                                                         [formula]
                           /  COEFF_MULT = has,             [R]
                           /  FONC_MULT_C  =  hci,       [fonction_C]
                                                         [formule_C]
                           /  COEF_MULT_C  =  aci,       [C]
                        ◊  Digital_ORDER =  nmordr,         [I]
                        ◊  ACCE = ac,                    [function]
                                                         [tablecloth]
                                                         [formula]
                        ◊  QUICKLY = VI,                    [function]
                                                         [tablecloth]
                                                         [formula]
                        ◊  DEPL = dp,                    [function]
                                                         [tablecloth]
                                                         [formula]
                        ◊  PHAS_DEG  =  /  0. ,             [DEFECT]
                                        /  phi,          [R]
                        ◊  PUIS_PULS =  /  0,            [DEFECT]
                                        /  nor,             [Is]
```

Operands and keywords specific to the seismic analysis

```
                        ◊  MULT_SUPPORT =   /   'NOT',          [DEFECT]
                                            /   'YES',
                        ◊  DIRECTION = (dx, Dy, dz, drx, dry Martini, drz),
   [l_R]
                        ◊  GROUP_NO  =  lgrno,                  [l_groupe_no]

                        ◊  CORR_STAT  = 'YES'
                           ♦ D_FONC_DT  =  dfdt,                [function]
                           ♦ D_FONC_DT2 =  dfdt2,               [function]
                ),

       ◊     / MODE_STAT = psi,                                 [mode_meca]
             / MODE_CORR = modcor,                              [mult_elas]
                                                                [mode_meca]

       ◊ EXCIT_RESU   =
         _F (    ♦ RESULT        = resuforc,
   [dyna_harmo]
                                                                [harm_gene]
                                                                [dyna_trans]
                                                                [tran_gene]
             ◊  /COEF_MULT   =  have,                              [R]
                /COEF_MULT_C =  aci,                            [C]
          ),
```

various types of non-linearity

```
       ◊  BEHAVIOR =    _F (
                              ♦ RELATION = | 'DIS_CHOC',
                                           | 'ROTOR_FIS',
                                           | 'PALIER_EDYOS',
                                           | 'BUCKLING',
                                           | 'ANTI_SISM',
                                           | 'DIS_VISC',
                                           | 'DIS_ECRO_TRAC',
                                           | 'RELA_EFFO_DEPL',
                                           | 'RELA_EFFO_VITE',
                                           | 'YACS',

             # If RELATION == 'DIS_CHOC' :
                    ◊  ENTITLE = int,                       [l_Kn]

                    ♦  /  GROUP_NO_1  =  grno1,             [group_no]
                          ◊  GROUP_NO_2  =  grno2,          [group_no]
                       /  GROUP_MA    =  grma,              [group_ma]

                    ♦  OBSTACLE =   obs,                    [obstacle]
                    ♦  NORM_OBST =  NOR,                    [listr8]
                    ◊  ORIG_OBST =  ori,                    [listr8]
                    ◊  GAME =       / 1. ,                  [DEFECT]
                                    / game,                    [R]

                    ◊  ENG_VRIL =   gamma,                  [R]

                    ◊  DIST_1 =  dist1,                     [R]
                    ◊  DIST_2 =  dist2,                     [R]

                    ◊  UNDER_STRUC_1 =  ss1,                [K8]
                    ◊  UNDER_STRUC_2 =  ss2,                [K8]
                    ◊  REFERENCE MARK =    / 'TOTAL',
   [DEFECT]
                                   / nom_sst,               [K8]
```

```
        ◊  RIGI_NOR =    kN,                          [R]
        ◊  AMOR_NOR =    / 0. ,                       [DEFECT]
                         / Cn,                        [R]
        ◊  RIGI_TAN =    / 0. ,                       [DEFECT]
                         / kt,                        [R]
        ◊  AMOR_TAN =    / ct,                        [R]
        ◊  FRICTION =/ 'NOT'                      [DEFECT]
                         / 'COULOMB'
                            ♦ COULOMB = driven        [R]
                         / 'COULOMB_STAT_DYNA'
                            ♦ COULOMB_STAT = driven [R]
                            ♦ COULOMB_DYNA = mud    [R]
        ◊  ONE-WAY = / 'NOT'              [DEFECT]
                     / 'YES'

# If RELATION == 'ROTOR_FISS' :
        ♦  GROUP_NO_G   =  grnog,                    [group_no]
        ♦  GROUP_NO_D   =  grnod,                    [group_no]
        ♦  ANGL_INIT =  0.0,                         [DEFECT]
        ◊  ANGL_ROTA =  0.0,                         [function]
        ♦  K_PHI     =  kphi                         [function]
        ♦  DK_DPHI   =  dkdphi                       [function]

# If RELATION == 'ANTI_SISM' :
        ♦  GROUP_NO_1   =  grno1,                    [group_no]
        ♦  GROUP_NO_2   =  grno2,                    [group_no]
        ◊  RIGI_K1 =     / 0. ,                      [DEFECT]
                         / kN,                       [R]
        ◊  RIGI_K2 =     / 0. ,                      [DEFECT]
                         / kN,                       [R]
        ◊  THRESHOLD_FX =  / 0. ,                       [DEFECT]
                         / Py,                       [R]
        ◊  C =           / 0. ,                      [DEFECT]
                         / C,                        [R]
        ◊  THEN_ALPHA =  / 0. ,                      [DEFECT]
                         / alpha,                    [R]
        ◊  DX_MAX =      / 1. ,                      [DEFECT]
                         / dx,                       [R]
        ),

# If RELATION == 'DIS_VISC' :
        ♦  GROUP_NO_1   =  grno1,                    [group_no]
        ♦  GROUP_NO_2   =  grno2,                    [group_no]
        ♦  /  K1        =  k1,                       [R]
           /  UNSUR_K1  =  usk1,                     [R]
        ♦  /  K2        =  k2,                       [R]
           /  UNSUR_K2  =  usk2,                     [R]
        ♦  /  K3        =  k3,                       [R]
           /  UNSUR_K3  =  usk3,                     [R]
        ♦  C            =  C,                        [R]
        ♦  PUIS_ALPHA   =  /  0.5,                   [DEFECT]
                           /  alpha,                 [R]
        ◊  ITER_INTE_MAXI  =  / 20,                  [DEFECT]
                              / iter,                [I]
        ◊  RESI_INTE_RELA  =  / 1.E-06,              [DEFECT]
                              / resi,                [R]

# If RELATION == 'DIS_ECRO_TRAC' :
        ♦  GROUP_NO_1   =  grno1,                    [group_no]
        ♦  GROUP_NO_2   =  grno2,                    [group_no]
        ♦  FX           =  fx,                       [function]
        ◊  ITER_INTE_MAXI  =  / 20,                  [DEFECT]
                              / iter,                [I]
        ◊  RESI_INTE_RELA  =  / 1.E-06,              [DEFECT]
                              / resi,                [R]

# If RELATION == 'BUCKLING' :
     ♦  GROUP_NO_1   =  grno1,                       [group_no]
```

```
                    ♦  GROUP_NO_2    =  grno2,                    [group_no]
                    ♦  OBSTACLE = obs,                            [obstacle]
                    ◊  ORIG_OBST = ori,                           [listr8]
                    ♦  NORM_OBST = NOR,                           [listr8]
                    ◊  ENG_VRIL = gamma,                          [R]
                    ◊  GAME = / 1. ,                              [DEFECT]
                             /jeu,                                [R]
                    ◊  DIST_1 = dist1,                            [R]
                    ◊  DIST_2 = dist2,                            [R]
                    ◊  REFERENCE MARK =    /'TOTAL',
        [DEFECT]
                                / nom_sst ,                       [K8]
                    ◊  RIGI_NOR = kN,                             [R]
                    ◊  FNOR_CRIT = film,                          [R]
                    ◊  FNOR_POST_FL = fseuil,                     [R]
                    ◊  RIGI_NOR_POST_FL = k2,                     [R]

                 # If RELATION == 'RELA_EFFO_DEPL' :
                    ♦  GROUP_ NO    =  grnoe,                     [group_no]
                    ◊  SOUS_STRUC   =  ss,                        [K8]
                    ◊  NOM_CMP      =  nomcmp,                    [K8]
                    ♦  FUNCTION     =  F,                         [function]

                 # If RELATION == 'RELA_EFFO_VITE' :
                    ♦  GROUP_NO  =  grnoe,                        [group_no]
                    ◊  SOUS_STRUC   =  ss,                        [K8]
                    ◊  NOM_CMP      =  nomcmp,                    [K8]
                    ♦  FONCTION     =  F,                         [function]

              ),
```

End of the mot key concerning the seizure of the parameters of non-linearity

```
           ◊  VERI_SHOCK = _F (
                        ◊  STOP_CRITERE  = /   'YES',             [DEFECT]
                                           /   'NOT',
                        ◊  THRESHOLD =  /   0.5,                     [DEFECT]
                                        /   S,                    [R]
                        ),

           ◊  ENERGY =_F (
                           ◊  CALCULATION  =  'YES',
   [DEFECT]
                           )

           ◊  FILING =_F ( ♦  | /LIST_INST = list,             [listr8]
                                / INST      = in,                [R]
                                  ◊ CRITERION =  /'RELATIVE',     [DEFECT]
                                                 /'ABSOLUTE',
                                  # If 'RELATIVE' == CRITERION :
                                  ◊ PRECISION = / 1.E-06,       [DEFECT]
                                                / prec,         [R]
                                  # If 'ABSOLUTE' == CRITERION :
                                  ♦ PRECISION = prec,          [R]
                               |  PAS_ARCH  = ipa,              [I]
                             ◊ CHAM_EXCLU =  |'DEPL',
                                             |'QUICKLY',
                                             |'ACCE',
                        ),

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

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

```
        # so transitory on generalized basis
      ◊  IMPRESSION = _F (   /  ◊  ALL=   'YES',              [DEFECT]
                             ◊  LEVEL  =  | 'DEPL_LOC',
                                          | 'QUICKLY_LOC',
                                          | 'FORC_LOC',
                                          | 'RATE_CHOC',
                             ◊  INST_INIT =  Ti,              [R]
                             ◊  INST_END  =  tf,              [R]
                          /  ◊  UNITE_DIS_VISC      =  unit1  [I]
                             ◊  UNITE_DIS_ECRO_TRAC  = unit2  [I]
                ),

      ◊  TITLE  =  title,                                    [l_Kn]

    )
```

Structure of data produced:

if BASE_CALCUL == 'PHYS'	and	TYPE_CALCUL == 'TRAN'	dyna_trans
if BASE_CALCUL == 'PHYS'	and	TYPE_CALCUL == 'HARM'	dyna_harmo
if BASE_CALCUL == 'GENE'	and	TYPE_CALCUL == 'HARM'	harm_gene
if AsType (MATR_RIGI) == matr_asse_pres_c			acou_harmo
if BASE_CALCUL == 'GENE'	and	TYPE_CALCUL == 'TRAN'	tran_gene

Contents

3 Operands of indirection

3.1 TYPE_CALCUL

This keyword which makes it possible to make the choice between transitory calculation (TYPE_CALCUL=' TRAN') and harmonic calculation (TYPE_CALCUL=' HARM).

3.2 BASE_CALCUL

This keyword makes it possible to make the choice between a calculation on physical basis (BASE_CALCUL=' PHYS') and a calculation on modal basis (BASE_CALCUL=' GENE').

The keywords specific to each type of calculation are described in the following paragraphs:
- Transitory calculation of answer on modal basis (§5)
- Transitory calculation of answer on physical basis (§6)
- Harmonic calculation of answer (§7)

4 Operands common to any type of calculation

4.1 Operand TITLE

◊ TITLE = title
Title of the structure of data result [U4.03.01].

4.2 Operand SOLVEUR

◊ SOLVEUR

This keyword factor is optional. It makes it possible to define the method of resolution of the system. Syntax is described in the document [U4.50.01].
In the current version, the method MULT_FRONT is not available for the resolution of the systems with generalized matrices.

5 Transitory calculation of answer on modal basis

Let us consider the model with the finite elements of a linear structure, presenting mechanisms of dissipations internalS, subjected to external efforts, being able as well to be known a priori (loadings) that in front of being evaluated progressively (efforts of shocks, contact, etc). In the temporal field, the relation of balance is written:

$$\left[K_e q(t) + D_v \dot{q}(t) + M \ddot{q}(t)\right] = B u(t)$$

where K_e is the matrix of stiffness of the structure, D_v the matrix associated with viscous dissipation, and M the matrix of mass. One notes in addition q the vector of the degrees of freedom. The external term of efforts is defined by the product of a matrix of localization of the efforts B and of a vector u specifying the temporal evolution of the excitation. This writing makes it possible to separate the space segments and temporal from an often noted effort $f(t)$. One will thus have, in this case,

$$f(t) = Bu(t)$$

The resolution of the problem on the basis of complete model presented in the relation above can be crippling for models of industrial size. To circumvent this difficulty, one proposes to build a scale model having the same spectral properties as the complete problem. One thus applies the existence of a base of reduction T_r who allows the reasonable representation of the behavior of the structure on the waveband of interest. Under these conditions, one thus has

$$q \approx T_r q_r$$

Terms q_r linear combination correspond to the amplitudes generalized of the complete problem project on the basis T_r. These amplitudes thus check, in the case general:

$$\left[T_r^T K_e T_r\right] q_r(t) + \left[T_r^T D_v T_r\right] \dot{q}_r(t) + \left[T_r^T M T_r\right] \ddot{q}_r(t) = T_r^T B u(t)$$

One thus solves here a system moreover small of which unknownES are the generalized amplitudes q_r.

$\left[T_r^T K_e T_r\right]$ indicate the matrix of generalized stiffness.
$\left[T_r^T D_v T_r\right]$ indicate the matrix of generalized damping.
$\left[T_r^T M T_r\right]$ indicate the matrix of generalized mass.

The base T_r is made up in the majority of the cases of clean modes of the studied structure. By abuse language, one it appeLwill lera thereafter “bases modal”.

5.1 Generalized matrices

In the case of a calculation by modal recombination, the generalized matrices must be established by the operator PROJ_MATR_BASE [U4.63.12] or by the macro-order PROJ_BASE [U4.63.11], starting from the same modal base.
In the case of a calculation by dynamic under-structuring, the generalized matrices must be established by the operator ASSE_MATR_GENE [U4.65.04], starting from same generalized classification.

- MATR_MASS = my

Matrix of mass of the generalized system.
Concept of the type matr_asse_gene_R.

♦ MATR_RIGI = laughed

Matrix of rigidity of the generalized system.
Concept of the type matr_asse_gene_R.

◊ MATR_AMOR = amndt

Matrix of damping of the generalized system.
Concept of the type matr_asse_gene_R.
This option is not available with the method 'DEVOGE'.

5.2 Keyword AMOR_MODAL

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 $-C\dot{X}$.

5.2.1 Operands AMOR_REDUIT / LIST_AMOR

◊ / AMOR_REDUIT =

List of reduced depreciation ($\eta_1, \eta_2, \ldots, \eta_n$ percentages of damping criticizes) corresponding to each mode of the system in the form of list of realities.
This option is not available in dynamic under-structuring because reduced depreciation must be defined for each substructure separately (operator MACR_ELEM_DYNA [U4.65.01]).

Note:

If the number of reduced depreciation given is lower than the number of basic vectors used in the modal base, depreciation of the additional vectors is taken equal to the last damping of the list.

/ LIST_AMOR = l_amor

Name of the concept of the type listr8 containing the list of reduced depreciation.

5.3 Diagrams of integration. Keyword SCHEMA_TEMPS

Under this keyword one can inform a diagram of integration with, possibly, his parameters. Diagrams availableS are to be declared under the operand DIAGRAM.

5.3.1 Operand DIAGRAM

◊ DIAGRAM =
Choice of the digital method of resolution.
In the case of a classical calculation by modal recombination, the user has several methods of the explicit type, an integral method and method of an implicit type.
In the case of a calculation by dynamic under-structuring [R4.06.04], the transitory method of calculating on modal basis calculated by under-structuring supports all the evoked diagrams of integration. On the other hand, the transitory method of calculating on the "bases" of the substructures supports only the diagram of type centered difference and the diagrams with step in adaptive time.

5.3.1.1 DIAGRAM = 'NEWMARK' : implicit scheme

This diagram allows only the integration of linear problems. It is the diagram by default for the resolution. One can specify the parameters of integration β and γ :

◊ BETA = beta

Value of the parameter β for the method of NEWMARK. By default $\beta = 0.25$.

◊ GAMMA = gamm

Value of the parameter γ for the method of NEWMARK. By default $\gamma = 0.5$.

5.3.1.2 DIAGRAM = 'DIFF_CENTRE' : diagram clarifies order 1

This diagram supports calculation with taking into account of the whole of localised non-linearities available.

5.3.1.3 DIAGRAM = 'DEVOGE' : diagram clarifies order 4

The diagram of DEVOGELAERE supports calculation with taking into account of the whole of localised non-linearities available.

5.3.1.4 DIAGRAM = 'ADAPT_ORDRE2' : diagram clarifies order 2

This diagram (called 'ADAPT' in the previous versions of the code) calculation with taking into account of the whole of localised non-linearities available supports. This method uses the diagram of the centered differences, the algorithm of adaptation of the step of time is based on the calculation of a "apparent frequency":

$$f_{APt} = \frac{1}{2\pi}\sqrt{\left|\frac{\ddot{x}_t - \ddot{x}_{t-1}}{x_t - x_{t-1}}\right|}$$

One specifies hereafter the operands specific to the method of integration per step of adaptive times. They are the operands following of the keyword factor INCREMENT :

◊ NB_POIN_PERIODE = NR

Many points per apparent period. It is this parameter which fixes the precision of calculation. It must be at least equal to 20; its value by default (50) guarantees a satisfactory precision (about 1%) in most case.

◊ VITE_MIN =

Method of calculating the speed of reference used to evaluate the apparent frequency.
When the denominator of the frequency connects ($x_n - x_{n-1}$) becomes weak, this one can become very high, which leads to an unjustified refinement of the step of time. To cure it, the algorithm uses the following criterion:

$$\frac{|x_n - x_{n-1}|}{\Delta t} \leq V_{min} \Rightarrow f_{APn} = \frac{1}{2\pi}\sqrt{\left|\frac{\ddot{x}_n - \ddot{x}_{n-1}}{V_{min}\Delta t}\right|}$$

V_{min} can be calculated in two ways different according to the value from VITE_MIN :

'NORM' = $V_{min}(t_n) = \frac{\|V(t_n)\|}{100}$ for all the degrees of freedom.

Can be used:

- if the system has several degrees of freedom,
- if the order of magnitude of displacement is not too different according to the degrees of freedom.

'MAXIMUM' = $V^i_{min}(t_n) = \frac{Max_{0<t_p<t_n}(|V^i(t_p)|)}{100}$ for the degree of freedom i .

Can be used:

- if the system has a small number of degrees of freedom (from 1 to 3),

- for a system with several degrees of freedom, if the order of magnitude of displacement is very different according to the degrees of freedom (for example in the presence of degrees of freedom of Lagrange under - structuring),
- if the order of magnitude speed does not vary too much in the course of time.

◊ NMAX_ITER_PAS = NR

Maximum number of reductions of the step of time per step of calculation. It is by default equal to 16, which limits the coefficient of reduction of the step to $0,75^{16}=10^{-2}$ by iteration (when the step of time is too high, one takes again calculation with a weaker step: $\Delta t_n'=0,75\Delta t_n$).

NMAX_ITER_PAS can be:

- increased to allow the step time to fall in a more brutal way,
- decreased if the step of time seems excessively refined, for example in the presence of discontinuities (solid friction, discontinuous excitation,…).

If, at a given moment, one reaches this maximum number of successive reductions of the step of time, then the code nevertheless will consider that the final step is correct and will pass to the following step. A message of alarm is then transmitted, which announces a possible risk of loss of precision and which advises with the user to start again calculation with parameters modified (while playing on NOT, NMAX_ITER_PAS and/or COEF_DIVI_PAS) to allow to cross the difficulty with a step of smaller time.

◊ COEF_MULT_PAS = cmp

Coefficient of increase in the step when the error is sufficiently weak:

$$\Delta t_n<\frac{0,75}{Nf_{APn}}\Rightarrow\Delta t_{n+1}=\mathrm{cmp}\,\Delta t_n .$$

Its value by default ($\mathrm{cmp}=1.1$) guarantees stability and precision, but it can in general be increased (with more until 1.3) to accelerate integration.

◊ COEF_DIVI_PAS = cdp

Coefficient of refinement of the step of time (>1) when the error is higher than 1, that the iteration count maximum (N_MAX_ITER_PAS) is not reached and that the step of minimal time is not reached:

$$\Delta t_n<\frac{1}{Nf_{APn}},\ N_{iter}<N_{iter\_max}\ \text{and}\ \Delta t_n>\mathrm{plr}\,\Delta t_{initial}$$

$$\Rightarrow\Delta t_n=\frac{\Delta t_n}{\mathrm{cdp}}$$

The value by default is of 1.33333334, that is to say a reduction of a factor 0.75.

◊ PAS_LIMI_RELA = plr

Coefficient applied to the step of initial time to define the limit of refinement and thus the step of minimal time:

The value by default is of 1.33333334, that is to say a reduction of a factor 0.75.

$$\Delta T_{min}=\mathrm{plr}\ \Delta t_{initial}$$

5.3.1.5 DIAGRAM = 'RUNGE_KUTTA_54' : explicit diagram with adaptive step.

This diagram is part of the family of the diagrams of integration of the Runge-Kutta type. In particular, it is the explicit diagram of integration of Dormand-Prince (54) [R5.06.04] with step of adaptive time.
The diagram 'RUNGE_KUTTA_54' support the taking into account of all nonthe - linearities available in the operator.

The calculation of the step of optimal time is done by control of the error between the approximations of order 5 and 4 of the prediction of the vector of state (concatenation of the vectors of displacement and speed).

This diagram is based on the condition of control of the following relative error:

$$err \leq tol$$

with

$$err = \frac{1}{n}\sum_i \sqrt{\left(\frac{y_{iI} - \hat{y}_{iI}}{sc_i}\right)^2} \quad \text{and} \quad sc_i = MAX\left(|y_{i0}|, |y_{iI}|\right) + \alpha$$

where

- y_{iI} is the value of the prediction of order 5 of the component i vector of state y
- $\hat{y}_{1i}$ is the value of the prediction of order 4 of the component i vector of state y
- n is the size of the vector of state y
- y_{0i} is the value of the component i vector of state y with the actual position

◊ TOLERANCE = tol
Value of control of relative error given by the user. By default it is worth 1.E-3.

◊ ALPHA = alpha
Value of regularization given by the user intervening in the expression of sc_i. By default it is worth 1.E-3.

5.3.1.6 DIAGRAM = 'RUNGE_KUTTA_32' : explicit diagram with adaptive step.

Like the diagram 'RUNGE_KUTTA_54', the diagram 'RUNGE_KUTTA_32' fact part of the family of the diagrams of integration of the Runge-Kutta type. In this case, it is the explicit diagram of integration of Bogacki-Shampine (32) [R5.06.04] with step of adaptive time.
Like the preceding diagram, it supports the taking into account of the whole of non-linearities available in the operator.

For this diagram, the calculation of the step of optimal time is done by control of the error between the approximations of order 3 and 2 of the prediction of the vector of state. The calculation of the step of optimal time, as for him, is done in a way similar to the preceding diagram.

5.3.1.7 DIAGRAM = 'ADAPT_ORDRE1' : diagram clarifies order 1

This diagram is an alternative of the preceding diagram 'ADAPT_ORDRE2'. It is in fact a version of the diagram of Euler with step of adaptive time. Apart from this difference, this diagram is used same manner as the adaptive diagram of order 2: the syntax of the keyword is the same one and the methods of piloting of the step of time too.

5.3.1.8 DIAGRAM = 'ITMI' : diagram integral for the calculation of the answer of mechanical systems very slightly deadened

This diagram of integration by integral method allows, for the slightly deadened systems, to obtain an exact answer provided that the dynamic matrices of mass, rigidity and of damping are diagonal.

5.4 Keyword INCREMENT

5.4.1 Operands LIST_INST / NOT/VERI_PAS/PAS_MINI/PAS_MAXI

♦ / LIST_INST = l_temp
Concept lists realities of the type listr8.
List of realities defining the moments t_i of calculation of the solution

- Diagrams 'RUNGE_KUTTA_54' and 'RUNGE_KUTTA32':
  For the diagrams of the Runge-Kutta type, the keyword LIST_INST is not taken into account.

  / NOT = dt

- Diagrams 'DIFF_CENTRE', 'NEWMARK', 'ITMI':
  Pas de time of trans calculationitoire.

- Diagrams 'ADAPT_ORDRE1' and 'ADAPT_ORDRE2':

  Indicate the step of initial time used by the algorithm.
  This parameter must be sufficiently weak:
  - to allow the calculation of the static phases (which always uses the step of maximum time),
  - to start the algorithm correctly.

  It must however be sufficiently high not to penalize the whole of calculation.

- Diagrams 'RUNGE_KUTTA_54', 'RUNGE_KUTTA32' and 'DEVOGE':

  Indicate the step of initial time suggested by the user. If the error of prediction between the control statements checks $err \leq 1$, then it is the first step of calculation. If not, the algorithm automatically chooses the step of time necessaries in order to check this condition. Thereafter, the choice of the step of time in the algorithms of Runge-Kutta is managed automatically.

◊ VERI_PAS = reference mark

Checking of the step of computing time compared to step of given time limits according to the highest frequency of the modes of the modal base considered or the bases of under - structures.

Operands specific to an integration by step of adaptive times with the diagrams 'ADAPT_ORDRE1', 'ADAPT_ORDRE2' like 'RUNGE_KUTTA_54' and 'RUNGE_KUTTA_32' and 'DEVOGE'.

◊ PAS_MAXI = dtmax

Maximum value of the step of time. If the conditions of increase in the step of time are met, the step of current time will be able to then increase up to this limiting value.

If the user does not give a value to this optional parameter, diagrams adaptive of type ADAPT_ORDRE1/2 will consider a value noted dts starting from the cut-off frequency of the base (possibly corrected by the stiffnesses of shocks). On the other hand, them others diagrams adaptive (Runge-Kutta, De Vogelaere) will not have any limitation superiorE in terms of step of time.

To find the operation of the previous versions of the code, it is enough to force:
$dtmax = dt$, therefore the same value with the parameter NOT that with PAS_MAXI.

◊ PAS_MINI = dtmin

Minimal value of the step of time. If the conditions of reduction in the step of time are met, the step of current time will be able to then decrease up to this limiting value.
If the user does not give a value to this optional parameter, then the code will calculate the step of minimal time near to the precision of the machine.
To find the operation of the previous versions of the code, it is thus enough not to define PAS_MINI.

Notice important:

To force a diagram of integration to pass in not-constant mode, it is enough to choose PAS_MAXI= PAS_MINI=PAS=dt

5.4.2 Operands INST_INIT/INST_FIN/NUME_FIN

◊ INST_INIT = to

Methods 'DIFF_CENTRE', 'DEVOGE', 'NEWMARK', 'ADAPT_ORDRE1' and 'ADAPT_ORDRE2':

Moment of beginning of transitory calculation. In the event of recovery, the keyword is used ETAT_INIT : under this keyword, the initial moment is recovered with the operand INST_INIT or taken equal to the last moment of filed preceding calculation. The operand INST_INIT must thus be only used if there is no resumption of a preceding calculation.

◊ / INST_FIN = tf

Moment of end of simulation.

/ NUME_FIN = tf

Number of the moment of end of calculation in LIST_INST

5.5 Keyword ETAT_INIT

Keyword factor which allows a continuation of a transitory calculation, while taking as initial state:

- that is to say a result resulting from a calculation by modal synthesis preceding EXCIT (RESULT);
- maybe displacements and speeds expressed in the form of generalized assembled vectors EXCIT (DEPL and QUICKLY)

Note:

- *This functionality is not available for a calculation by transitory under-structuring without double projection.*
- *Displacements and speeds generalized must be establish by the operator PROJ_VECT_BASE [U4.63.13] starting from the modal base used for the generalized matrices of rigidity or by the operator RECU_GENE [U4.71.03] applied to a preceding calculation.*

5.5.1 Operands RESU/DEPL/QUICKLY

♦/ RESULT = tran

Concept of the type tran_gene resulting from a preceding calculation with DYNA_VIBRATED.

/ I DEPL = C

Concept of the type vect_asse_gene, initial generalized displacements.

I QUICKLY = vo

Concept of the type vect_asse_gene, initial generalized speeds.

5.5.2 Operands INST_INIT/NUME_ORDR

◊ / INST_INIT = to

Moment of preceding calculation to in the case of extract and take as initial state a recovery. In the absence of this operand, the moment of recovery is taken equal to the last moment of filed preceding calculation.

/ NUME_ORDRE = nuord

Désigne the number of filing of preceding calculation to in the case of extract and take as initial state a recovery.

5.5.3 Operand CRITERION

◊ CRITERION

Indicate with which precision the research of the moment must be done:

'RELATIVE' : interval of research [(1-prec) .instant, (1+prec) .instant]
'ABSOLUTE' : interval of research [moment-prec, instant+prec]

The criterion is 'RELATIVE' by default.

5.5.4 Operand PRECISION

◊ PRECISION = / 1.E-06 [DEFECT]
/ prec [R8]

Indicate with which precision the research of the moment must be done.

5.6 Description of the loading under separate variables: keyword EXCIT

◊ EXCIT

Keyword defining the loading. This keyword must be repeated as many times as there are vectors generalized loading f_i. The total loading is the sum of these vectors loading. This keyword makes it possible to define the loading under has the shape of generalized vectors multiplied by multiplying functions.

5.6.1 Operands VECT_ASSE_GENE/NUME_ORDRE

The loading is taken into account in the form of vector project on the modal basis EXCIT=_F (VECT_ASSE_GENE) or in the form of modal component EXCIT =_F (NUME_MODE) or both at the same time.

~ VECT_ASSE_GENE = v

Generalized vector allowing to describe the space distribution of the loading.
Concept of the type vect_asse_gene.
The generalized vectors must be establish by the operator PROJ_VECT_BASE [U4.63.13] starting from the modal base used for the generalized matrices. In the case of a calculation by dynamic under-structuring, the generalized vectors must be establish by the operator ASSE_VECT_GENE [U4.65.05] starting from the generalized classification used for the generalized matrices.

/ NUME_ORDRE = nmordr

Sequence number of the mode of excitation of the structure (Attention! One should not confuse the sequence number of the mode – given by modal calculation in the order where they have calculated – and the number of the mode, entitled in *Code_Aster* NUME_MODE).

5.6.2 Operand FONC_MULT/COEF_MULT

♦ / FONC_MULT = F

Function of time (function) allowing to describe the temporal evolution of the vector loading.

/ COEF_MULT = has

Multiplying coefficient of the generalized vector (constant actual value compared to time).

5.7 Keyword EXCIT_RESU

Keyword allowing to define a loading in the form of a generalized temporal evolution, without separation of variables (case more the general). This temporal evolution can be calculated starting from the operator PROJ_BASE, option RESU_GENE, which carries out the projection of a transitory dynamic result (dyna_trans).

5.7.1 Keyword RESULT

♦ / RESULT = resu_gene

Structure of data resu_gene defining the generalized loading.

5.7.2 Operand COEF_MULT

◊ / COEF_MULT = F

Multiplying coefficient, is worth 1.0 by default.

5.8 Typical case of the seismic analysis

5.8.1 Taking into account of the modes neglected by static correction: keywords CORR_STAT, MODE_CORR and D_FONC_*

During the seismic analysis of an excited mono structure, it is possible to take into account, a posteriori, the static effect of the neglected modes. In this case, at the time of the return on the physical basis, calculated relative displacements (respectively relative speeds and accelerations) are corrected by a pseudo-mode.
One will find the details of this kind of correction in [R4.05.01].

Inside the keyword factor EXCIT, CORR_STAT=' OUI' the taking into account of the modes neglected by static correction allows, it is then obligatory to inform the keywords MODE_CORR, D_FONC_DT and D_FONC_DT2.

◊ MODE_CORR = modcor

Concept of the type mult_elas product by the macro-order MACRO_ELAS_MULT [U4.51.02] or mode_meca who corresponds to the linear static response of the structure to a unit loading of type forces imposed (constant acceleration) in the direction of the earthquake considered.
It is noted that there is as much loading case than of direction of earthquake.

◊ EXCIT = _F (CORR_STAT)

If MODE_CORR is present, CORR_STAT=' OUI' allows to take into account the contribution of the modal correction a posteriori for each occurrence of the keyword EXCIT.

◊ EXCIT = _ F (D_FONC_DT and D_FONC_DT2)

D_FONC_DT and D_FONC_DT2 are respectively the derivative first and derived seconds of the time of the definite accélérogramme, in each seismic direction considered, by the operand FONC_MULT. They balance the contribution of the modal correction a posteriori for each occurrence of the keyword EXCIT in order to respectively obtain the corrections speed and acceleration on the physical basis.

Note:

- *The taking into account of the static correction excludedT that of the multi-supports.*
- *The concept* mult_elas *must be based on a coherent classification of the equationsS (even profile and even option of renumerotation) with that of the system solved in the operator* DYNA_TRAN_MODAL.
- *With* i *ème occurrence of the keyword* EXCIT *corresponds* i *ème elastic solution of* MODCOR *.*
- *So that the static correction is actually taken into account at the time of the return towards the physical coordinates in the operator* REST_GENE_PHYS *or* RECU_FONCTION *it is necessary to specify* CORR_STAT_=' OUI'.

5.8.2 Taking into account of the multi-supports: keywords MODE_STAT, MULTI_APPUI and ACCE, QUICKLY, DEPL

In the case of a multimedia structure, in order to restore the sizes calculated in the absolute reference mark or to take into account nonlocated linearities, it is necessary to calculate the answer generalized by taking of account the component of training.
For more details, one will refer to the reference [R4.05.01].

Keywords MODE_STAT, MULT_APPUI, ACCE, QUICKLY, DEPL, DIRECTION and GROUP_NO) specific to the taking into account of the multimedia character must be simultaneously present.
One cham_no resulting from the projection of one CALC_CHAR_SEISME represent the vector of excitation on the support. It should not be forgotten, even if information can appear redundant with the data of the support and the direction of earthquake.

◊ MODE_STAT = psi

Concept of the type mode_meca product by the order MODE_STATIQUE [U4.52.14] which corresponds to (3 or 6) nb_supports static modes (where nb_supports is the number of supports which undergo a different acceleration).

◊ EXCIT = _F (MULT_APPUI)

If one calculates the seismic answer of a multimedia structure, MULT_APPUI = 'YES', one compared to each moment, the vector of absolute displacements of each point of shock considered, in order to determine if there is shock and to calculate the corresponding forces of shock. If not, MULT_APPUI = 'NOT', one compared to each moment, the vector of relative displacements of each node likely to shock.

◊ EXCIT = _F (/ ◊ ACCE = ac,
◊ QUICKLY = VI,
◊ DEPL = dp)

Names of the functions acceleration (ACCE), speed (QUICKLY) and displacement (DEPL) imposed during the calculation of the seismic answer of multimedia structures.

Note:

If the structure is mono-excited, the accélérogramme is defined by the keyword FONC_MULT.

◊ EXCIT = _F (DIRECTION = (dx, Dy, dz, drx, dry Martini, drz))

Components of the vector giving the direction of the earthquake in the total reference mark.

◊ EXCIT = _F (GROUP_NO = lgrno)

List of the names of group of nodes corresponding to the supports concerned where the earthquake is imposed.

◊ EXCIT = _F (VECT_ASSE_GENE = v)

Vector project of the seismic excitation (resulting from CALC_CHAR_SEISME [U4.63.01])

5.9 Taking into account of a transient number of revolutions

5.9.1 Operand VITESSE_VARIABLE

Specify if the number of revolutions of the rotor is variable according to time (VITESSE_VARIABLE = 'YES' for the transients of speed) or constant (VITESSE_VARIABLE = 'NOT').

5.9.2 Operands VITE_ROTA, MATR_GYRO, ACCE_ROTA and MATR_RIGY

These operands are the parameters defining the transient number of revolutions.

If VITESSE_VARIABLE = 'YES', then should be informed the following parameters:

- ♦ QUICKLY _ROTA = function giving the angular law velocity imposed on the rotor
- ♦ MATR _GYRO = gyroscopic matrix of damping

◊ ACCE_ROTA = function giving the law of angular acceleration imposed on the rotor

◊ MATR_RIGY = gyroscopic matrix of stiffness

Note:

If ACCE_ROTA is not provided, it is neglected (IE. no digital derivation from QUICKLY_ROTA).

If VITESSE_VARIABLE = 'NOT', it is necessary to inform the value number of constant revolutions.

◊ VITE_ROTA = livesess of rotation of the tree [by default 0.0]

5.10 Keyword VERI_CHOC

Keyword which makes it possible to evaluate a posteriori, the aptitude of the modal base to represent the impacts correctly.

If VERI_CHOC is present, one calculates in each node of shock and for each mode, the rate of reconstitution of the static solution: $t_s = K_{statique} \sum_{i=1}^{n} \frac{({}^T\Phi_i . F_{impo})^2}{k_i}$ and, for information, the rate of reconstitution of the shearing action: $t_N = \sum_{i=1}^{n} \frac{{}^T\Phi_i . F_{impo}}{k_i} . ({}^T F_{impo} . K . \Phi_i)$. One calculates then the values cumulated on the whole of the modes which constitute the modal base used.

It is checked that the report of the flexibility neglected (static flexibility minus reconstituted static flexibility) on the flexibility of shock remains lower than the value given by the operand THRESHOLD (THRESHOLD 0.5 by default is worth) if not:

- if STOP_CRITERE = 'YES' the execution of the program is stopped (it is the case by default);
- if STOP_CRITERE = 'NOT' one continues the execution of the program with emission of an alarm.

Note:

- *This functionality is available only for obstacles of the type plan or bi_plan .*
- *If the rate of reconstitution of the static solution is lower than the value of the threshold, one advises with the user to supplement the modal base by the local modes at the points of shock which have an important local flexibility.*
- *The formula is not applicable in the event of static modes (noninvertible matrix of rigidity). Calculation continues then without checking of the criteria of shock and the user is informed by it.*

5.11 Keyword BEHAVIOR

This keyword factor makes it possible to define a non-linear behavior localised (applied to a node). Several types of behavior are available.

5.11.1 Not localised linearities of standard shock and friction: DIS_CHOC

◊ RELATION = 'DIS_CHOC

This keyword is used for the study of the answer of structures (generally slim) whose displacements are limited in one (or several) (S) - not specified a priori by the user by the presence of an obstacle (the various types of obstacles available are described in the documentation [U4.44.21] of the operator DEFI_OBSTACLE), of another antagonistic structure.

5.11.1.1 Operand ENTITLE

◊ ENTITLE = int

Heading (eight characters to the maximum) allowing to name non-linearity. If nothing is specified by the user, the heading is the name node GROUP_NO_1.

5.11.1.2 Operands GROUP_NO_1/GROUP_NO_2. /GROUP_MA

♦ GROUP_NO_1
Name of the group of node of the structure to which the condition of non-linearity relates.
In the case of a non-linear calculation by dynamic under-structuring, one indicates under this keyword the node of shock pertaining to the first substructure (the different ones under - structures do not belong to the same grid).

◊ GROUP_NO_2
Name of the group of node of the second structure to which the condition of non- linearity relates. This operand is specific to the definition of a contact between two mobile structures.
In the case of a non-linear calculation by dynamic under-structuring, one specifies the node of shock coinciding with the node indicated in GROUP_NO_1, but pertaining to the second substructure.

Note:
It is checked that the groups of nodes contain well one and only one node.

♦ GROUP_MA
One can also enter the nodes of shocks in opposite in the shape of meshs SEG2 drawn the grid. Thus one preserves the same way of describing the shocks as for DYNA_NON_LINE with the discrete elements of shock (DIS_CHOC). One can enter a list of GROUP_MA.

5.11.1.3 Operand OBSTACLE

♦ OBSTACLE = obs
Name of concept of the type obstacle defining the geometry of an indeformable obstacle or the form game between two antagonistic structures wraps. It is produced by the operator DEFI_OBSTACLE [U4.44.21].

5.11.1.4 Operand NORM_OBST

♦ NORM_OBST = NOR
List of 3 realities defining the normal in the plan of cut of the obstacle, i.e. the vector X_{loc} . One advises that X_{loc} that is to say direction of neutral fibre or a generator of the studied structure.

5.11.1.5 Operand ORIG_OBST

◊ ORIG_OBST = ori
List of 3 realities defining the position of the origin of the obstacle in the total reference mark (obligatory keyword in the case of shocks between a mobile structure and a fixed wall). In the case of shocks between two mobile structures, the code considers by default that the origin is located in the middle of the two nodes of shock GROUP_NO_1 and GROUP_NO_2.

5.11.1.6 Operand GAME

◊ GAME = game
In the case of a shock enters a mobile structure and an indeformable obstacle, the operand GAME represent:
- the half-distance inter-plans for obstacles of the type PLAN_Y and PLAN_Z
- the ray of the circular obstacle for an obstacle of the type CIRCLE

This keyword is unutilised in the case of obstacles discretized by segments of the type DISCRETE.

Note:
The obstacle of the type PLAN_Y or PLAN_Z comprise in fact two obstacles plans. Thus if the user wishes to model the shock on a single level, not to be constrained by the rebound of the structure studied on the symmetrical level, one advises with the user to very push back it

far (cf [3.6.1.6 Figure - has]), J represents the real game between the studied structure and the obstacle .

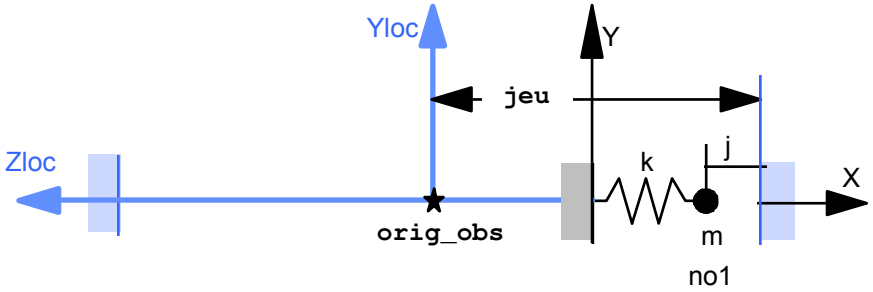


Figure 3.6.1.6 - has: System mass-arises impacting a fixed wall

Notice :

The keyword GAME in the case of shock between mobile structures is not used.

The various cases of games are represented in the documentation of DEFI_OBSTACLE [U4.44.21].

5.11.1.7 Operand ANGL_VRIL

◊ ANGL_VRIL = gamma

γ , angle in degrees defining the angular position of the local reference mark of the obstacle in its plan.

By convention, the normal n with the plan of cut of the obstacle, NORM_OBST the axis defines X_{loc} local reference mark. One passes from the total reference mark X, Y, Z with the reference mark of the plan of the obstacle n, y_2, z_2 by a product of two rotations of angles α around Z then β around transformed y_1 of Y.
The position of the obstacle in this plan is obtained by a rotation of angle β around the normal direction X_{loc} (cf [3.6.1.7 Figure - has]).

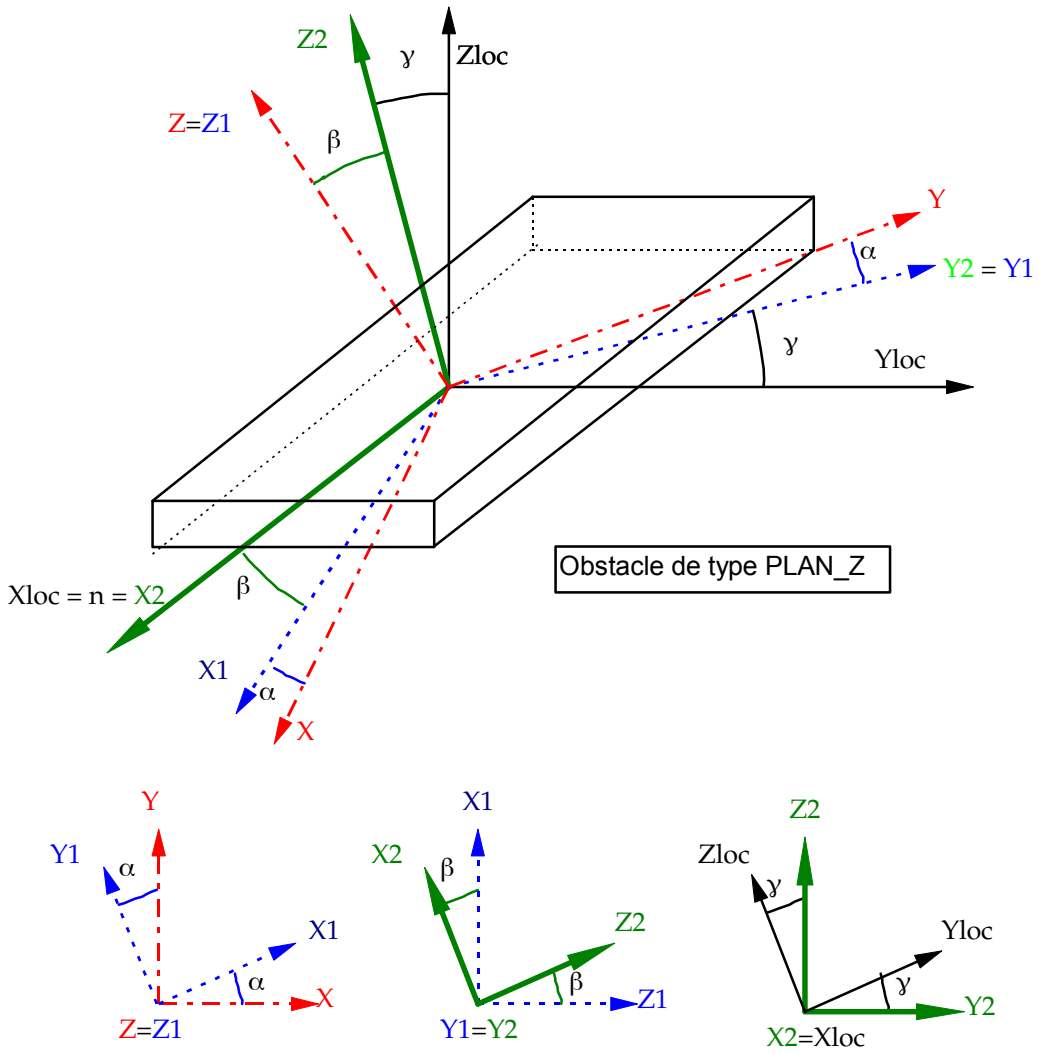


Figure 3.6.1.7 - has: Rotations allowing to pass from the total reference mark to the local reference mark of the obstacle.

Angles α and β are automatically given starting from the normal with the obstacle n. The local reference mark X_{loc}, Y_{loc}, Z_{lo} results then from the reference mark $n, y_{2,} z_2$ by rotation of an angle of gimlet ANGL_VRIL around n.

Note:

- *If the user does not specify anything, the angle of gimlet is calculated by the code in the case of shocks between mobile structures with obstacles of the type BI_PLAN.*
- *With regard to the other types of obstacles, the value by default of gamma is zero.*

5.11.1.8 Operands DIST_1/DIST_2

◊ DIST_1 = dist1

Distance characteristic of matter surrounding GROUP_NO_1: no1.
Operand specific to the contact between two mobile structures.

◊ DIST_2 = dist2

Distance characteristic of matter surrounding GROUP_NO_2: no2.
Operand specific to the contact between two mobile structures.

Note:

- *DIST_1 and DIST_2 are defined within the meaning of the outgoing normals of the two solids out of screw - with-screw (DIST_1 and DIST_2 are positive because they represent the thickness of the studied structures).*
- *Because of the calculation of the normal distance from shock, the sum of DIST_1 and of DIST_2 must be sufficiently large compared to the supposed amplitude of the relative displacement of the nodes of shocks (cf [R5.06.03]).*

5.11.1.9 Operands SOUS_STRUC_1/SOUS_STRUC_2

◊ SOUS_STRUC_1 = ss1

Name of the substructure which contains the node of shock informing the keyword GROUP_NO_1.

◊ SOUS_STRUC_2 = ss2

Name of the substructure which contains the node of shock informing the keyword GROUP_NO_2.

5.11.1.10 Operand REFERENCE MARK

◊ REFERENCE MARK = reference mark

Specify the reference mark in which the position of the obstacle is defined.

/ 'TOTAL'

The absolute position of the obstacle is defined independently of rotations and translations to which the various substructures are subjected.

/ nom_sst

Name of a substructure.
The position and the normal of the obstacle are given in the reference mark used to define the coordinates of the nodes of the substructure nom_sst, the position and the normal finales of the obstacle being the result of rotation and the translation to which is subjected under - structure.

5.11.1.11 Operand RIGI_NOR

♦ RIGI_NOR = kN

Value of the normal rigidity of shock (unit N/m in USI).

5.11.1.12 Operand AMOR_NOR

◊ AMOR_NOR = Cn

Value of the normal damping of shock (unit $N\,m/s$ in USI).

5.11.1.13 Operand RIGI_TAN

♦ RIGI_TAN = kt

Value of the tangential rigidity of shock (unit N/m in USI).

5.11.1.14 Operand AMOR_TAN

◊ AMOR_TAN = ct

Value of the tangential damping of shock (unit $N\,m/s$ in USI).

Note:

If a stiffness k_t is specified and that the keyword AMOR_TAN is absent, the code calculates a damping optimized in order to minimize the residual oscillations in adherence according to the formula:

$$c_t = 2\sqrt{(k_i + k_t)\,m_i} - 2\xi_i\sqrt{k_i\,m_i}$$

where I am the index of the dominating mode in the answer of the structure.

5.11.1.15 Operand FRICTION

◊ FRICTION =/'NOT'

The condition of contact is without friction.

/ 'COULOMB'
♦ COULOMB = driven
Value of the coefficient of friction (without dimension).

/ 'COULOMB_STAT_DYNA'
♦ COULOMB_STAT = driven
Value of the adhesion coefficient (without dimension).
♦ COULOMB_DYNA = mud
Value of the coefficient of friction (without dimension).

5.11.1.16 Operand ONE-WAY

◊ ONE-WAY = / 'NOT', [DEFECT]
/ 'YES',

Activation of one-way friction allowing to define a nonisotropic coefficient of friction in the plan of the obstacle. Cette option is usable as well with the friction of the type 'COULOMB' that with friction 'COULOMB_STAT_DYNA'. It is used to model the bearing and the friction of a roller on a rail, while authorizing rising.

With a friction of type 'COULOMB' :
The coefficient of friction is worth 0. along the axis indicated in NORM_OBST and driven in the perpendicular direction *(cf [R5.06.03])* .

With a friction of type 'COULOMB_STAT_DYNA' :
The adhesion coefficient is worth 0. along the axis indicated in NORM_OBST and driven in the perpendicular direction. The coefficient of friction is worth 0. along the axis indicated in NORM_OBST and mud in the perpendicular direction.

5.11.2 Not localised linearities of fissured rotor: ROTOR_FISS

The operands following are specific to transitory calculation with localised non-linearity of type "rotor fissured" for calculations of line of trees modelled in 1D (beam). The crack is considered completely included in a section of the rotor. It is delimited by two distinct nodes but confused coordinates, one connected to the left part of the line of trees, the other with the right part. They respectively represent the left lip and the right lip of the crack.
The behavior of the crack is given by a law of stiffness of crack and its derivative. This law is in addition given by calculations 3D into quasi-static. It does not depend on the geometry of the rotor but only of and the coefficient fissure shape of dimension.

◊ RELATION = 'ROTOR_FISS'
/ ♦ GROUP_NO_G = group of node naming the left lip of the crack
♦ GROUP_NO_D = group of node naming the lip right-hand side crack
♦ ANGL_INIT = initial angle of the bottom of crack compared to its definition in the law of behavior of crack [by default 0.0]
◊ ANGL_ROTA = function giving the imposed law of angular position of the bottom of crack compared to its definition in the law of behavior of crack (transients speed)
♦ K_PHI = law of behavior in stiffness of the crack
♦ DK_DPHI = derived from the law of behavior in stiffness

Orientation of the axis of the rotor:
To respect the trigonometrical direction of rotation, it is important to direct the rotor well: the axis of the rotor is automatically directed by the crack, while going from the left edge towards the edge right-hand side of the crack.

5.11.3 Localised non-linearity: ANTI_SISM

◊ RELATION = 'ANTI_SISM'

This relation ANTI_SISM is incompatible with a calculation by dynamic under-structuring. It makes it possible to calculate the nonlinear force which exists if an antiseismic device is placed between the two antagonistic nodes whose names are specified by the keywords (GROUP_NO_1 and GROUP_NO_2):

$$F_D = K_2 x + \frac{(K_1 - K_2) x}{\sqrt{1 + \left(K_1 \frac{x}{P_y}\right)^2}} + C\, sign(\dot{x}) \left| \dot{x} \frac{x}{x_{max}} \right|^{\alpha}$$

◊ RIGI_K1, RIGI_K2, SEUIL_FX, C, PUIS_ALPHA and DX_MAX

Parameters of the force due to the presence of an antiseismic device.

By way of an example, the values of the parameters for an antiseismic device of BULGE type are:

$K1 = 6.E+06\, N/m$, $K2 = 0.53E+06\, N/m$, $Py = 1200.$, $C = 0.07E+05\, Nm/s$, $alpha = 0.2$ and $xmax = 0.03\, m$ (if the problem is posed in USI).

5.11.4 Non-linearity: DIS_VISC

It is a nonlinear viscoelastic behavior between two nodes, *cf.* [R5.03.17]. This behavior affects only the degree of freedom DX room of the element. Direction x local from the element goes from node 1 to node 2.

Note:

- *It is a nonlinear viscoelastic behavior between two nodes, it does not have there thus a finite element between the nodes concerned (just a relation of behavior). During the calculation of the reduced modal base, it can be judicious to define an element with an elastic stiffness corresponding to the tangent with the behavior of the device [R5.03.17].*
- *The results concerning the effort, viscous and relative displacements between the two nodes, as well as the dissipation of the non-linear device can be saved in a directly exploitable file by the orders of Code_Aster . The file design is done by the single-ended spanner word UNITE_DIS_VISC who is under the key word factor IMPRESSION order.*

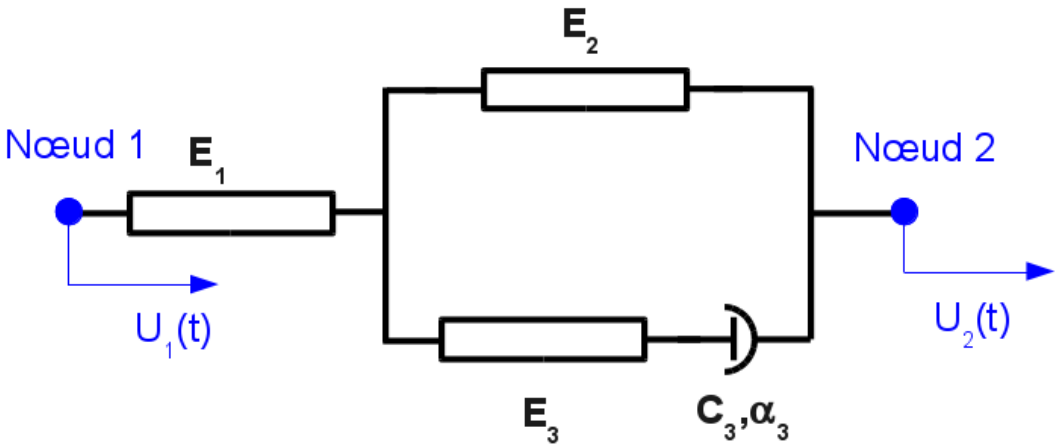


Figure 5.11.4-a : diagram of the device.

5.11.4.1 Syntax

◊ RELATION = 'DIS_VISC'

```
♦  GROUP_NO_1          = grno1,                          [group_no]
♦  GROUP_NO_2          = grno2,                          [group_no]

♦  / K1                = k1,                                  [R]
   / UNSUR_K1          = usk1,                                [R]
♦  / K2                = k2,                                  [R]
   / UNSUR_K2          = usk2,                                [R]
♦  / K3                = k3,                                  [R]
   / UNSUR_K3          = usk3,                                [R]
♦  C                   = C,                                   [R]
♦  PUIS_ALPHA          =/0.5                             [defect]
                         /alpha,                              [R]

◊  ITER_INTE_MAXI      =/20                              [defect]
                         /iter                                [I]
◊  RESI_INTE_RELA      =/1.0E-06                         [defect]
                         /resi                                [R]
```

5.11.4.2 Operands related to the position of the device

- GROUP_NO_1
- GROUP_NO_2

Name of the groups of node of the structure between which the non-linear device is placed. LE groups node should contain one node.
During calculation, it is necessary to know the direction of the non-linear device because it functions only in its axis. It is necessary thus that the distance between the two nodes is nonworthless.

5.11.4.3 Operands related to the behavior

The behavior DIS_VISC is a nonlinear viscoelastic rheological behavior, of type Zener extended, allowing to schematize the behavior of a uniaxial shock absorber, enters two nodes.

For the local direction x (and only that one) of the device, one provides five coefficients. Their units must be in agreement with the unit of the efforts, the unit lengths and the unit of time of the problem:

- K1 : elastic stiffness of element 1 of the rheological model,
- K2 : elastic stiffness of element 2 of the rheological model,
- K3 : elastic stiffness of element 3 of the rheological model,

- UNSUR_K1 : elastic flexibility of element 1 of the rheological model,
- UNSUR_K2 : elastic flexibility of element 2 of the rheological model,
- UNSUR_K3 : elastic flexibility of element 3 of the rheological model,

- PUIS_ALPHA : power of the viscous behavior of the element α ,
- C : coefficient of the viscous behavior of the element.

There exist conditions to respect on the values of the coefficients so that the tangent is always defined:

$k1 \geq 10^{-8}$ $usk1 \geq 0$ $k3 \geq 10^{-8}$ $usk3 \geq 0$ $usk2 \geq 10^{-8}$ $k2 \geq 0$ $C \geq 10^{-8}$
$10^{-8} \leq \alpha \leq 1$

One cannot thus have at the same time $usk1 = 0$, $usk3 = 0$ and $k2 = 0$ i.e. the case of the shock absorber alone.

5.11.4.4 Operands related to the convergence of the behavior of the device

```
◊   ITER_INTE_MAXI     =/20                          [defect]
                         /iter                           [I]
◊   RESI_INTE_RELA     =/1.0E-06                     [defect]
                         /resi                           [R]
```

These operands have the same meaning as when they are used with the order STAT_NON_LINE/COMPORTEMENT [U4.51.11].
The relation of behavior DIS_VISC require to solve a nonlinear system by a method of Runge-Kutta of order 5 with adaptive step. The control of the algorithm (iteration count and residue) are used to test convergence and to adapt the step if need be.

5.11.5 Non-linearity: DIS_ECRO_TRAC

The behavior DIS_ECRO_TRAC is a nonlinear behavior, allowing to schematize the behavior of a uniaxial device, only according to the degree of freedom DX.

Note:

It is a nonlinear behavior between two nodes, it does not have there thus a finite element between the nodes concerned (just a relation of behavior). During the calculation of the base modal reduced, it can be judicious to define an element with an elastic stiffness corresponding to the tangent with the behavior of the device [R5.03.17].

The non-linear behavior is given by a curve $F_x = fonction(\Delta U_x)$:

- Δu_x represent the relative displacement of the 2 nodes in the local reference mark of the element.
- F_x represent the effort expressed in the local reference mark of the element.

The only data necessary is the function describing the non-linear behavior. This function must respect the criteria according to:

- It is a function within the meaning of *Code_Aster* : defined with the operator DEFI_FONCTION,
- The interpolations on the ordinate and x-axes are linear,
- The name of the X-coordinate at the time of the definition of the function is DX,
- The prolongations on the left and on the right of the function are excluded,
- The function must be defined by at least 3 points,
- The first point is $(0.0, 0.0)$ and must be given.
- The function must be strictly increasing.
- The derivative of the function must be lower or equal to its derivative to the point $(0.0,0.0)$.

5.11.5.1 Syntax

```
◊    RELATION = 'DIS_ECRO_TRAC'

     ♦   GROUP_NO_1         = grno1,                  [group_no]
     ♦   GROUP_NO_2         = grno2,                  [group_no]

     ♦   FX                 = fx                      [function]

     ◊   ITER_INTE_MAXI     =/20                        [defect]
                              /iter                          [I]
     ◊   RESI_INTE_RELA     =/1.0E-06                   [defect]
                              /resi                          [R]
```

5.11.5.2 Operands related to the position of the device

- GROUP_NO_1
- GROUP_NO_2

Name of the groups of node of the structure between which the non-linear device is placed. group of node should contain one node.
During calculation, it is necessary to know the direction of the non-linear device because it functions only in its axis. It is necessary thus that the distance between the two nodes is nonworthless.

5.11.5.3 Operands related to the behavior

The behavior DIS_ECRO_TRAC is a nonlinear behavior enters two nodes.

For the local direction x (and only that one) of the device, one provides a function. The units must be in agreement with the unit of the efforts, the unit lengths.

$$Effort = Fonction(\text{déplacement relatif des } 2 \text{ nœuds})$$

5.11.5.4 Operands related to the convergence of the behavior of the device

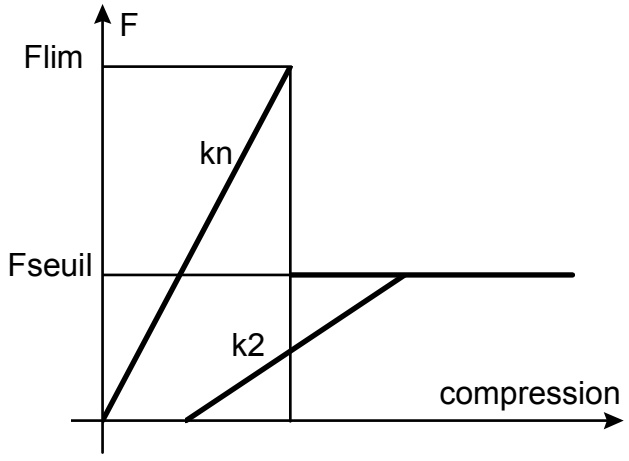
```
◊  ITER_INTE_MAXI     =/20                    [defect]
                        /iter                      [I]
◊  RESI_INTE_RELA     =/1.0E-06               [defect]
                        /resi                      [R]
```

These operands have the same meaning as when they are used with the order STAT_NON_LINE/COMPORTEMENT [U4.51.11].
The relation of behavior DIS_ECRO_TRAC require to solve a nonlinear system by a method of Runge-Kutta of order 5 with adaptive step. The control of the algorithm (iteration count and residue) are used to test convergence and to adapt the step if need be.

5.11.6 Non-linearity: BUCKLING

◊ RELATION = 'BUCKLING'

This relation is used for the detection of possible buckling and the evaluation of the residual deformation of an element at the time of a shock between two mobile structures or a mobile structure and a fixed wall. The force of reaction at the time of a shock with taking into account of buckling can be summarized by the following diagram:



It is considered that there is buckling if the force of reaction F reached the limiting value $F_{\lim}$ defined by the user. The normal rigidity of shock after buckling $k2$ is different from rigidity before buckling kn .

OnlyES operands specific to the keyword BUCKLING are detailedEs. The other keywords make it possible to define the places of shock and are identical to the operands for the relation DIS_SHOCK.

◊ FNOR_CRIT = film

Normal force limits which involves the buckling of the structure.

◊ FNOR_POST_FL = fseuil
Normal force limits after buckling which causes a residual deformation of the structure.

◊ RIGI_NOR_POST_FL = k2
Value of normal rigidity after buckling.

5.11.7 Non-linearity: RELA_EFFO_DEPL

◊ RELATION = 'RELA_EFFO_DEPL'
This relation makes it possible to define a relation force-displacement or moment - rotation on a degree of freedom given in the shape of a nonlinear curve.

5.11.7.1 Operand GROUP_NO

♦ GROUP_NO = gr.No
Node of the structure to which the relation relates.

5.11.7.2 Operand SOUS_STRUC

◊ SOUS_STRUC = ss
Name of the substructure containing the node informing the operand GROUP_NO.

5.11.7.3 Operand NOM_CMP

◊ NOM_CMP = nomcmp
Name of the component of the node of the structure to which the relation relates.

5.11.7.4 Operand FUNCTION

♦ FUNCTION = F
Name of the nonlinear function.
The nonlinear relation must be defined on *on* $]-\infty,\infty[$. The non-linear phase in postprocessings corresponds to the beach of moments when the nonlinear relation was not-worthless.

The equilibrium equation, for a structure subjected to a horizontal acceleration of ground a_x in the direction x , and having terms of correction coming from non-linearities, is written:

$$M\ddot{x}+C\dot{x}+Kx=-Ma_x+F_c$$

where F_c is the corrective force due to nonthe linearity of the ground. It can be, for example, defined by the following relation (cf case test SDND103):

$$F_c=kx-f(x)$$

with:

$$\text{if } x\geq x_0,\ f(x)=k\left(\frac{|x|}{x_0}\right)x .$$

In example Ci above, one thus imposes, under the operand RELATION the function:

$$F_c(x)=\frac{k}{x_0}x[|x|-x_0] \quad \text{for } |x|>x_0$$
$$F_c(x)=0 \quad \text{for } |x|\leq x_0$$

5.11.8 Non-linearity: RELA_EFFO_VITE

◊ RELATION = 'RELA_EFFO_VITE'
This relation makes it possible to define a relation force-speed on a degree of freedom of a node given in the form of a nonlinear function.

Operands GROUP_NO, SOUS_STRUC, NOM_CMP and FUNCTION the same direction for the relations has RELA_EFFO_DEPL and RELA_EFFO_VITE. They are thus not detailed in this paragraph.

5.12 Keyword FILING

◊ FILING
Keyword factor defining filing.

5.12.1 Operand LIST_INST/INST

◊ / LIST_INST = l_arch
List of entireties defining the moments of calculation for which the solution must be filed in the concept result tran_gene.

◊ / INST
Moments of calculation for which the solution must be filed in the concept result tran_gene .

5.12.2 Operand PAS_ARCH

◊ PAS_ARCH = ipa
Entirety defining the periodicity of filing of the solution of transitory calculation in the concept result tran_gene.
If ipa = 5 all 5 pas de calculation are filed.
Whatever the option of filing chosen, one files it first and it last step of time and all the associated fields to allow possible recovery.
By default one files all the steps of calculation.

5.12.3 Operand CRITERION

◊ CRITERION =
Indicate with which precision the research of the moment to be filed must be done:
'RELATIVE' : interval of research [(1-prec) .instant, (1+prec) .instant]
'ABSOLUTE' : interval of research [moment-prec, instant+prec]
The value by default of the search criterion is 'RELATIVE'.

5.12.4 Operand PRECISION

◊ PRECISION = / 1.E-06 [DEFECT]
/ prec [R]
Indicate with which precision the research of the moment to be filed must be done.

5.13 Operand INFORMATION

◊ INFORMATION = imp
Entirety allowing to specify the level of impression in the file MESSAGE.
If INFO=1, one prints a summary of dynamic calculation with the options chosen, the matrices and the number of non-linearities considered. The advance of calculation is deducted by slices of 5 % of the total duration of simulation.

If INFORMATION : 2, one prints, besides written information if INFORMATION 1 is worth, advance with shorter slices of 1 %. In the presence of located non-linearities, one prints for each obstacle following extra information :

- The number and type of the obstacle;
- The name and coordinates in the total reference mark of the node of shock (of the nodes of shock in the case of a shock between mobile structures);
- Orientation, in the total reference mark, of the normal to the obstacle;
- The value of the angle of gimlet;
- The value of the initial game;

If mode VERI_CHOC is activated, one also prints for each node of shock and each mode, values of the local stiffnesses of shock and the rate of local flexibility and the local flexibility.

5.14 Operand IMPRESSION

◊ IMPRESSION

Keyword factor which makes it possible to print in the file RESULT sizes, nonprintable by an operator of impression, such as local displacement, local speed, forces of contact to the nodes of shock and the value cumulated on all the modes of the modal base of projection of the rate of reconstitution of the static solution.

5.14.1 Operands ALL/LEVEL

The keyword LEVEL allows to print one or more table (X) among 'DEPL_LOC', 'VITE_LOC', 'FORC_LOC' and 'TAUX_CHOC'. With ALL = 'YES' (value by default), the four tables are printed.

5.14.2 Operands INST_INIT/INST_FIN

These two keywords make it possible to the user to filter the impressions in each loop on the steps of time.

5.14.3 Operand UNITE_DIS_VISC

◊ UNITE_DIS_VISC = links

The results concerning the effort, viscous and relative displacements between the two nodes, as well as the dissipation of the non-linear device can be savedS in a directly exploitable file by the orders of *Code_Aster* .

5.15 Phase of control

5.15.1 Checking on the matrices

In the case of a calculation by modal recombination, one checks that the generalized matrices result quite from a projection on a common basis and with the same number of basic vectors. In the case of a calculation by dynamic under-structuring, one checks that the generalized matrices result quite from the same generalized classification.

5.15.2 Checking and council on the choice of the step of time for the diagrams DIFF_CENTRE, DEVOGE and NEWMARK :

One makes sure that the step of selected time checks the stability conditions of the digital diagram (criterion of CFL):

- in the case of NEWMARK, stability is always assured but the going beyond the criterion can induce a lack of precision on the result and is announced by a message; calculation continues (with the risk to produce a not very precise or false result).
- in the case of diagrams of DIFF_CENTRE and DEVOGE, if the operand VERI_PAS is worth 'YES' (value by default), the execution is stopped, a step of minimum time is proposed. If the operand VERI_PAS is worth 'NOT' or if it is about a diagram adaptive, a message of alarm is transmitted and calculation continues (with the risk to produce a not very precise or false result).

In a transitory analysis without non-linearity, it should be taken care that the step of time is such as:

$dt < 0,1/f_n$ for NEWMARK and DEVOGE

$dt < 0,05/f_n$ for DIFF_CENTRE

f_n being the highest frequency of the modes of the modal base considered.

Note:

It is mentioned that with nonlocalised linearities the step of selected time must be sometimes much lower than this advised value.

5.15.3 Production run for adaptive diagrams :

The execution is stopped when the step of time reaches a minimal step equal to PAS_MINI.

Note:

S diagramS ADAPT_ORDRE1/2 (centered differences) do not restore in an exact way the own pulsations of a system, which leads to important miscalculations in the two following cases:

- *Calculation of one very a large number of periods of free oscillations;*
- *Calculation of the oscillations of a system very slightly deadened ($\xi < 10^{-3}$) excited on a frequency of resonance.*

In these two cases, it is often necessary to increase the parameter NB_POIN_PERIODE.

Methods 'ADAPT_ORDRE1' and 'ADAPT_ORDRE2' can be used under-structuring.

The step of time can be recovered by the operator RECU_FONCTION, with following syntax:

```
not = RECU_FONCTION (
       RESU_GENE = dynamoda
       NOM_CHAM = 'PTEM'
       ….)
```

5.16 Taking into account of the effects of interaction fluid-structure

One describes Ci below the keywords specific to the calculation of the answer of linear mechanical systems very slightly deadened with couplings fluidelastic possibly associated with non- linearities located with the nodes of the shocks type and frictions.

◊ BASE_ELAS_FLUI = mix

Base modal used for calculation.

Concept of the type melasflu product by the operator CALC_FLUI_STRU [U4.66.02] which contains the whole of the modal bases calculated for different speedS of flow definite. This keyword is obligatory for the method 'ITMI'.

Transitory calculation on modal basis modified by the coupling fluidelastic is carried out by taking of account the values of added depreciation, which had with the flow of the fluid, which is present in the concept melasflu of entry . **Modal depreciation, recovered base fluidelastic, those well informed under the keyword replace *total* AMOR_REDUIT of the operator DYNA_TRAN_MODAL.**

◊ NUME_VITE_FLUI = Nvitf

Rate of flow retained for calculation (sequence number).

Allows to extract in the concept melasflu the modal base corresponding to the rate of flow retained (cf [U4.66.02]).

6 Transitory calculation of answer on physical basis

The operator carries out the direct temporal integration of a transitory linear mechanical problem of the form:

$$\mathbf{M}\ddot{\mathbf{x}}+\mathbf{C}\dot{\mathbf{x}}+\mathbf{K}\mathbf{x}=\sum_i \alpha_i(t)\mathbf{F}_i(\mathbf{x})$$

where matrices $\mathbf{M},\mathbf{C},\mathbf{K}$ are the assembled real matrices of the problem finite elements (respectively) of mass, damping and rigidity of the system.
α_i are functions of time (cf. DEFI_FONCTION [U4.31.02]) and them $\mathbf{F}_i$ resulting from loadings in imposed force (cf are assembled vectors. AFFE_CHAR_MECA [U4.44.01]); they can be provided directly in the form of assembled vectors or loads which will be assembled in the algorithm.

The solution $(\mathbf{X},\dot{\mathbf{X}},\ddot{\mathbf{X}})$ is calculated on a temporal discretization t_i interval of study specified by the user.

6.1 Operand MODEL

◊ MODEL = Mo

Name of the model whose elements are the object of dynamic calculation.

This operand is obligatory when one applies an excitation of the type charges with the keyword EXCIT (cf [§4.7]).

6.2 Operand CHAM_MATER

◊ CHAM_MATER = chmat

Name of the affected material field on the model Mo, necessary when one applies an excitation of the type charges with the keyword EXCIT.

6.3 Operand CARA_ELEM

◊ CARA_ELEM = carac

Name of the characteristics of the elements of beam, hull etc, necessary when one applies an excitation of the type charges with the keyword EXCIT.

6.4 Matrices of the system

♦ MATR_MASS = m

Concept stamps assembled of type matr_asse_DEPL_R corresponding to the matrix of mass of the system.

♦ MATR_RIGI = K

Concept stamps assembled of type matr_asse_DEPL_R corresponding to the matrix of rigidity of the system.

◊ MATR_AMOR = C

Concept stamps assembled of type matr_asse_DEPL_R corresponding to the matrix of damping of the system.

Note:

The three matrices must be based on same classification and be built with the same mode of storage. It is true also of a matrix of damping built like linear combination of the matrices of rigidity and mass by the method of Rayleigh: to use the matrix of the matrix of mass supplements to build the matrix of damping and the matrix of diagonal mass (explicit diagrams such as DIFF_CENTRE or ADAPT) for integration in time can lead to a digital instability.

6.5 Diagrams of integration. Keyword SCHEMA_TEMPS

Under this keyword one can inform a diagram of integration with, possibly, his parameters. Diagrams availableS are to be declared under the operand DIAGRAM.

6.5.1 Operand DIAGRAM

|' NEWMARK'

Implicit diagram of integration of type NEWMARK. It is the diagram by default for the transitory analysis on physical basis.
One can specify the parameters of integration β and γ :

◊ BETA = beta

Value of the parameter β for the method of NEWMARK. By default $\beta=0.25$.

◊ GAMMA = gamm

Value of the parameter γ for the method of NEWMARK. By default $\gamma=0.5$.

See [R5.05.02] for the choice of other values.

|' WILSON'

Implicit diagram of integration of type WILSON. With this diagram one can inform:
◊ THETA = HT

Value of the parameter θ for the method of WILSON. By default $\theta=1,4$.
This diagram should not be used when one imposes nonworthless displacements via an assembled vector. See [R5.05.02].

| 'DIFF_CENTRE'

Diagram of integration clarifies by centered differences. The use of this diagram imposes certain enumerated restrictions of use on [§6.3]. The theoretical description of the diagram is made in [feeding-bottle 2].

| 'ADAPT_ORDRE2'

Diagram of integration clarifies with step of adaptive time, alternative of the diagram of the centered differences. The use of this diagram imposes certain enumerated restrictions of use on [§6.3] (see [feeding-bottle 2]).

Note:

*One cannot use the diagrams **explicit** (DIFF_CENTRE , ADAPT_ORDRE2) with **elements of plate and hull** (except SHB).*

6.6 Keyword ETAT_INIT

This functionality allows a continuation of a transitory calculation, by taking as initial state a result got by a preceding calculation with DYNA_LINE_TRAN. It also makes it possible to define initial conditions of fields type in the nodes.

Note:
For the diagrams of a higher nature (NEWMARK or WILSON), initial acceleration (acce_init) play an important role in the initialization of the diagram.

6.6.1 Operands RESULT

♦ / RESULT = Dy

Concept of the type dyna_trans resulting from a preceding calculation with DYNA_LINE_TRAN, and defining the initial conditions for new calculation.

6.6.2 Operands DEPL/ VITE/ACCE

/ DEPL = C

Concept corresponding to initial displacements (field with the nodes of size DEPL_R).

QUICKLY = vo

Concept corresponding at the initial speeds (field with the nodes of size DEPL_R).

ACCE = ao

Concept corresponding to initial accelerations (field with the nodes of size DEPL_R).
If the key word is present, one uses the field of acceleration entered to initialize the various diagrams of integration in time according to the algorithms described in the document [R5.05.02].
If it is absent one calculates an initial acceleration by the following formula:

$$M.ao = Fext(t = \text{to}) - C.vo - K.xo$$

Remarque important:
When the initial state of the dynamic system is defined by fields of DEPL, QUICKLY, and/or ACCE, the components of these fields which were not explicitly indicated during the creation of the fields are considered worthless during transitory dynamic calculation.

6.6.3 Operands NUME_ORDRE/ INST_INIT

◊ / NUME_ORDRE = nuord

nuord indicate the number of filing of preceding calculation to in the case of extract and take as initial state a recovery.

/ INST_INIT = to

Moment of preceding calculation to in the case of extract and take as initial state a recovery.

In the absence of NUME_ORDRE and INST_INIT, the moment of recovery is taken equal to the last moment of filed preceding calculation.

6.6.4 Operand CRITERION

◊ CRITERION =

Indicate with which precision the research of the moment must be done:
'RELATIVE' : interval of research [(1-prec) .instant, (1+prec) .instant]
'ABSOLUTE' : interval of research [moment-prec, instant+prec]
The value by default of the search criterion is 'RELATIVE'.

6.6.5 Operand PRECISION

◊ PRECISION = / 1.E-06 [DEFECT]

/ prec [R]

Indicate with which precision the research of the moment must be done.

6.7 Keyword EXCIT

◊ EXCIT =

Operand allowing to define several space-time excitations. Either by indicating a vector assembled correspondent to a loading, or of the loads which will lead to the calculation and the assembly of a second member. The assembled vector can be associated with a function with temporal evolution or a constant multiplying coefficient.

The total loading is the sum of the loadings defined by all the occurrences of the keyword EXCIT (cf [§4.7.2]).

6.7.1 Operands VECT_ASSE / LOAD

♦ / VECT_ASSE = vecti

Vector assembled correspondent with a loading (concept of the type cham_no_DEPL_R).

◊ / COEF_MULT = Ci

Multiplicative coefficient of the assembled vector vecti.

/ FONC_MULT = α_i

See [§4.7.2].

/ LOAD = chi

chi is the loading possibly comprising the evolution of a field of temperature specified by i ème occurrence of EXCIT.

See [§4.7.2].

6.7.2 Operand FONC_MULT

◊ FONC_MULT = α_i

α_i is the multiplicative function of the time of the assembled vector or loading specified with i ème occurrence of EXCIT.

The loading $\mathbf{ch}$ and boundary conditions for n occurrences of the keyword factor EXCIT are:

$$\mathbf{ch}(t)=\sum_{i=1}^{n}\alpha_i(t)\mathbf{ch}_i$$

The fields of temperature are not multiplied by α_i in thermomechanical analysis.

Notice important:

*The boundary conditions of type displacement imposed not no one can be imposed with an assembled vector or a load **; it is then necessary to use the diagram of Newmark imperatively** .*

6.7.3 Operands MULTI_APPUI / ACCE / QUICKLY / DEPL / DIRECTION / GROUP_NO/MODE_STAT

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].

6.8 Keyword EXCIT_RESU

Keyword allowing to define several complements of loading in the form of a transitory evolution of assembled vectors second members.

6.9 Keyword AMOR_MODAL

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 $-\mathbf{C}\dot{\mathbf{X}}$.

Note:

This way of introducing modal damping into a problem calculated on physical basis can reduce the properties of stability of the diagrams in time. In particular for the diagram of integration ' NEWMARK 'it can result in reducing the step of time compared to the step of time without damping to avoid digital divergences.

6.9.1 Operands MODE_MECA / AMOR_REDUIT / NB_MODE

♦ MODE_MECA = mode
♦ AMOR_REDUIT = l_amor
◊ 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 [§4.11]. It isT 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 in the form of 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.

6.10 Keyword 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].

6.11 Keyword INCREMENT

Keyword factor defining the moments of calculation.

6.11.1 Operands LIST_INST / NOT

- For the diagrams of Newmark and Wilson:

♦ / LIST_INST = l_temp

Concept lists realities of the type listr8.

List of realities defining the moments t_i of calculation of the solution

- For the diagrams of the centered differences and with pas de adaptive time:

/ NOT = dt

Indicate the step of time used by the algorithm. This keyword is obligatory for the diagram of the centered differences and the diagram adaptive and nonavailable for the diagrams of Newmark and Wilson.

For the adaptive diagram, it indicates at the same time the step of initial time and the step of maximum times used by the algorithm.

This parameter must be sufficiently weak:

- to allow the calculation of the static phases (which always use the maximum step),
- to start the algorithm correctly.

It must however be sufficiently high not to penalize the whole of calculation.

6.11.2 Operands INST_INIT / INST_FIN / NUME_FIN

For the diagrams of the centered differences and with step in adaptive time:

◊ INST_INIT = Ti

In the event of recovery one uses the keyword ETAT_INIT [§4.6]: under this keyword, the initial moment is recovered with the operand INST_INIT or taken equal to the last moment of filed preceding calculation.

The operand INST_INIT under INCREMENT must thus be only used if it did not take again there of a preceding calculation.

◊ / INST_FIN = tf

Moment of end of transitory calculation. Obligatory for the diagrams of the centered differences and with step in adaptive time.

/ NUME_FIN = nufin

Number of the moment of end of calculation in LIST_INST (only for the diagrams of Newmark and Wilson).

If INST_INIT is not present, the initial moment is zero.

6.11.3 Operands VITE_MIN / COEF_MULT_PAS / COEF_DIV_PAS / PAS_LIMI_RELA / NB_POIN_PERIODE / NMAX_ITER_PAS / PAS_MINI

These operands relate to only the diagram with step of adaptive time.

◊ VITE_MIN = / 'NORM' [DEFECT]
/ 'MAXIMUM'

Method of calculating the speed of reference used to evaluate the apparent frequency.

When the denominator of the apparent frequency $(x_n - x_{n-1})$ becomes weak, the apparent frequency can become very high, which leads to an unjustified refinement of the step of time. To cure it, the algorithm uses the following criterion for each degree of freedom i :

$$\frac{\left|x_n^i - x_{n-1}^i\right|}{\Delta t} \leq v_{min}^i \Rightarrow f_{AP_n} = \frac{1}{2\pi}\sqrt{\left|\frac{\ddot{x}_n^i - \ddot{x}_{n-1}^i}{v_{min}^i \Delta t}\right|}$$

v_{min}^i can be calculated in two ways different according to the value from VITE_MIN :

'NORM' : $v_{min}^i(t_n) = Max\left(\frac{Max\left(\dot{x}_{n+1/2}^k, \dot{x}_{n+1/2}^l\right)}{100}, 10^{-15} ms^{-1}\right)$ where k and l are the degrees of freedom of comparable nature that the degree of freedom i closest to i in classification (DX or DY or DZ ...).

'MAXIMUM' : $v_{min}^i(t_n) = \underset{0<t_p<t_n}{Max}\left(\frac{|v^i(t_p)|}{100}, 10^{-15} ms^{-1}\right)$ for the degree of freedom i .

Can be used if the order of magnitude speed does not vary too much in the course of time.

◊ COEF_MULT_PAS = cmp

Coefficient of déraffinement of the step of time (>1) when the error is sufficiently weak:

$\Delta t_n < \frac{0.75}{Nf_{AP_n}}$ since more 5 pas consecutive $\Rightarrow \Delta t_{n+1} = min(\mathbf{cmp}\,\Delta t_n, \Delta t_{max})$

with $\Delta t_{max} = \Delta t_{initial}$

Its value by default ($\mathbf{cmp} = 1.1$) guarantees stability and precision, but it can in general be increased (with more until 1.3) to accelerate integration.

◊ COEF_DIVI_PAS = cdp

Coefficient of refinement of the step of time (>1) when the error is higher than 1, that the iteration count maximum (NMAX_ITER_PAS) is not reached:

$\Delta t_n > \frac{1}{Nf_{AP_n}}$, $Niter < Niter_{max}$ and $\Delta t_n > \mathbf{plr} * \Delta t_{initial} \Rightarrow \Delta t_n = \frac{\Delta t_n}{\mathbf{cdp}}$

Its value by default is of 1.3334 , that is to say a reduction of a factor $0,75$.

◊ PAS_LIMI_RELA = plr

Coefficient applied to the step of initial time to define the limit of refinement and thus the step of minimal time:

$$\Delta t_{min} = \mathbf{plr} * \Delta t_{initial}$$

◊ NB_POIN_PERIODE = NR

Many points per apparent period. It is this parameter which fixes the precision of calculation. It must be at least equal to 20; its value by default (50) guarantees a satisfactory precision (about 1à 2%) in most case.

◊ NMAX_ITER_PAS

Maximum number of reductions of the step of time per step of calculation:

if $err>1$ and $N_{iter}<N_{iter}max$: $\Delta t_n=cdp*\Delta t_n$

It is by default equal to 16, which limits the coefficient of reduction of the step to $(1/1,33)^{16}=10^{-2}$ by iteration. NMAX_ITER_PAS can be:

- increased to allow the step time to fall in a more brutal way,
- decreased if the step of time seems excessively refined.

◊ PAS_MINI = dtmin

Minimal value of the step of time. If the conditions of reduction in the step of time are met, the step of current time will be able to then decrease up to this limiting value.
If the user does not give a value to this optional parameter, then the code will calculate the step of minimal time from PAS_LIMI_RELA.

6.12 Keyword FILING

◊ FILING =

Keyword factor defining filing. In the absence of this keyword factor, all the steps of time are filed.

Whatever the option of filing chosen, one files the last step of time and all the associated fields to allow a possible continuation.

6.12.1 Operands LIST_INST/INST

◊ / LIST_INST = list

List of realities defining the moments of calculation for which the solution must be filed in the concept result dyna_tran.

◊ / INST

Moments of calculation for which the solution must be filed in the concept result dyna_tran .

6.12.2 Operand PAS_ARCH

/ PAS_ARCH = ipa

Entirety defining the periodicity of filing of the solution of transitory calculation in the concept result dyna_trans.

If ipa = 5 all 5 pas de calculation are filed.

6.12.3 Operand CRITERION

◊ CRITERION =

Indicate with which precision the research of the moment to be filed must be done:
'RELATIVE' : interval of research [(1-prec) .instant, (1+prec) .instant]
'ABSOLUTE' : interval of research [moment-prec, instant+prec]
The value by default of the search criterion is 'RELATIVE'.

6.12.4 Operand PRECISION

◊ PRECISION = / 1.E-06 [DEFECT]
/ prec [R]

Indicate with which precision the research of the moment to be filed must be done.

6.12.5 Operand CHAM_EXCLU

```
◊  CHAM_EXCLU = (      | 'DEPL',
                       | 'QUICKLY',
                       | 'ACCE',
                    )
```

Allows to exclude filing from one or more fields among 'DEPL', 'QUICKLY' and 'ACCE'.

This exclusion is ignored for the last moment of calculation: the three fields are necessary for one CONTINUATION.

6.13 Phase of control

The use of the diagrams of the centered differences and adaptive imposes certain restrictions of use:

- these two diagrams require the use of a matrix of diagonal mass. A test checks that the matrix of mass was created with the option 'MASS_MECA_DIAG' of CALC_MATR_ELEM. In addition, the matrix of mass must be stored in line of sky,
- there should not be other boundary conditions only blocked degrees of freedom.
  A test checks that there are no boundary conditions of the connections type between degrees of freedom.
  It is not either possible to impose nonworthless displacements via an assembled vector,
- for the diagram of the centered differences, one makes sure that the step of selected time checks the stability conditions:
  $dt < 0{,}05 / f_{max}$ with $f_{max} = \max_{1 \le i \le nddl} \left(\frac{1}{2\pi} \sqrt{\frac{k_{ii}}{m_{ii}}} \right)$ and k_{ii} and m_{ii} diagonal terms of the matrices of stiffness and mass.

7 Harmonic calculation of answer

The following equation is solved:

$$(-j\omega^3 \mathrm{I} - \omega^2 \mathrm{M} + j\omega \mathrm{C} + \mathrm{K})x = \left\{ \sum_{i=1}^{k} h_i(f)\omega^{n_i} \mathrm{e}^{j\pi \frac{\varphi_j}{180}} g_i(\mathrm{P}) \right\}$$

Where:

K represent matrix of a real or complex rigidity

M represent a matrix of mass

C represent a matrix of viscous damping

I represent a matrix of acoustic impedance resulting from a formulation in displacement-pressure-potential.

P is a point running of the structure.

$\omega = 2\pi f$: pulsation of excitation

x : complex answer

The damping of the structure can be viscous or hysteretic [U2.06.03] [R5.05.04]. In the case of a damping hysteretic, one has a matrix of rigidity complexes and one solves the following equation:

$$(\mathrm{K} - \omega^2 \mathrm{M})x = \left\{ \sum_{i=1}^{k} h_i(f)\omega^{n_i} \mathrm{e}^{j\pi \frac{\varphi_j}{180}} g_i(\mathrm{P}) \right\}$$

With K : complex matrix of rigidity.

This operator is usable in imposed force and imposed (relative reference frame or absolute).

7.1 Operand RESULT

◊ RESULT = harm

Name of the structure of data result to enrich. This keyword is obligatory if one is in D-entering concept mode (reuse).

7.2 Operand MODEL

◊ MODEL = Mo

Name of the concept defining the model whose elements are the object of harmonic calculation.

7.3 Operand CHAM_MATER

◊ CHAM_MATER = chmat

Name of the concept defining the affected material field on the model Mo.

7.4 Operand CARA_ELEM

◊ CARA_ELEM = carac

Name of the concept defining the characteristics of the elements of beam, hulls, etc…

7.5 Operand MATR_MASS

♦ MATR_MASS = m

Name of the concept stamps assembled corresponding to the matrix of mass of the system.

7.6 Operand MATR_RIGI

♦ MATR_RIGI = K

Name of the concept stamps assembled corresponding to the matrix of rigidity of the system. A hysterical damping is obtained with a complex matrix of rigidity.

7.7 Operand MATR_AMOR

◊ MATR_AMOR = C

Name of the concept stamps assembled corresponding to the matrix of viscous damping of the system.

7.8 Keyword AMOR_MODAL

Keyword factor to inform damping in the shape of lists of damping reduced with operands following.

7.8.1 Operands AMOR_REDUIT / LIST_AMOR

/ AMOR_REDUIT = L η

List of all reduced depreciation: $(\eta_{1,}\eta_{2,}\ldots,\eta_{n})$.

/ LIST_AMOR = C η

Name of the concept of the type listr8 containing the list of reduced depreciation.

7.9 Operand MATR_IMPE_PHI

◊ MATR_IMPE_PHI = imp

Name of the concept stamps assembled corresponding to the matrix of impedance for a system fluid-structure whose formulation is in displacement-pressure-potential (u, p, φ) [R4.02.02].

7.10 Operands FREQ/LISTE_FREQ

♦ / FREQ = lf

List of all the frequencies of calculation: (f1, f2,…, fn).

/ LIST_FREQ = cf

Name of the concept of the type listr8 containing the list of the frequencies of calculation.

7.11 Operands TOUT_CHAM / NOM_CHAM

◊ / TOUT_CHAM = 'YES'
/ NOM_CHAM = | 'DEPL'
| 'QUICKLY'
| 'ACCE'

Choice of the fields to calculate to represent the answer: displacement, speed, acceleration or three.

7.12 Keyword EXCIT

♦ EXCIT

Operand allowing to define several excitations. Either by indicating a vector assembled correspondent to a loading, or of the loads which will lead to the calculation and the assembly of a

second member. For each occurrence of the keyword factor, one defines a component of the excitation in the form $(h(f), g(\mathrm{P}), \varphi)$.

7.12.1 Operands VECT_ASSE/VECT_ASSE_GENE/CHARGE

Allow to define $g(\mathrm{P})$ space discretization of the loading, in the form of a field with the nodes corresponding to one or more loads of force or imposed movement.

♦ / VECT_ASSE = vecti

Name of the concept produced by:

- the operator ASSE_VECTEUR in imposed force or imposed of displacement in an absolute reference frame. The amplitudes of the excitation can be defined in the concepts of the type charges corresponding. The expected field is a field with the nodes of size DEPL_R, DEPL_C or PRES_C.

/ VECT_ASSE_GENE = vect_gene

Name of the concept produced by:

- the operator PROJ_VECT_BASE who allows to project a vector assembled on a modal base or a basis of Ritz.
- the operator ASSE_VECT_GENE who allows to project a loading on a basis defined on a model generalized for calculations of dynamic under-structuring.

/ LOAD = chi

chi name of the concept of loading specified by I[ème] occurrence of EXCIT.
The keyword MODEL must be well informed if the keyword is used LOAD.

7.12.2 Operands FONC_MULT_C / COEF_MULT_C / FONC_MULT / COEF_MULT

Allow to define $h(f)$ law of evolution, complex or real, of the frequency, applied to all the components of the field to the node associated with this occurrence. Several opportunities are given:

♦ / FONC_MULT_C = hci

Name of the concept of the type fonction_C or formule_C defining a function $h(f)$ complex of the frequency f,

/ COEF_MULT_C = aci

Coefficient complexes multiplying loading, independent of the loading,

/ FONC_MULT = hi

Concept of the type function, formula or tablecloth defining a function $h(f)$ real of the frequency f,

/ COEF_MULT = have

Multiplying real coefficient of the loading, independent of the loading.

7.12.3 Operand PUIS_PULS

◊ PUIS_PULS = nor

Allows to define the power of the pulsation when the loading is function of the frequency; by default $N_I = 0$.

7.12.4 Operand PHAS_DEG

◊ PHAS_DEG = phi

Allows to define the phase of each component of the excitation in degrees compared to a single reference of phase; by default $\varphi_i = 0$.

7.12.5 Notice

For a problem with imposed movement, one defines the blocked degrees of freedom (conditions kinematics preliminary to the construction of cham_no) ; one can then choose an excitation:

- in imposed displacement $n = 0$, $\varphi = 0$ degree
- in imposed speed $n = 1$, $\varphi = 90$ degrees
- in imposed acceleration $n = 2$, $\varphi = 180$ degrees

7.13 Operand EXCIT_RESU

◊ EXCIT_RESU

This keyword factor makes it possible to define several complements of loading in the form of a harmonic evolution of type dyna_harmo assembled vectors second members, calculated on the physical basis.

7.13.1 Operand RESULT

This keyword makes it possible to define the seconds members complementary to extract for each frequency from calculation starting from a result already calculated from fields from nodal forces.

♦ RESULT = resuforc

Name of the concept of evolution harmonic of second members producedS by the sequence of the operator CALC_FORC_NONL [U4.84.21] in order to produce a transitory evolution of second members, and the operator REST_SPEC_TEMP [U4.63.34] to transform this transitory evolution into harmonic evolution. An example of use is provided in the case test SDLS119A.

7.13.2 Operand COEF_MULT_C

♦ COEF_MULT_C = aci

Coefficient complexes multiplying vector second member extracted the result resuforc for each frequency of calculation.

7.14 Operand INFORMATION

◊ INFORMATION = inf

Allows to carry out in the file message various intermediate impressions allowing to follow the advance of calculation.

By default, if INFO=1, one prints the advance of harmonic calculation with a step which corresponds to the maximum to 5 % of the full number of frequencies. The general rule is systematically to print the first and last frequencies as well as a maximum number of 20 frequencies in the medium.

If INFO=2, an impression is carried out for each frequency and makes it possible more precisely to follow the advance of calculation.