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Operator `STAT_NON_LINE`

1 Goal

To calculate the mechanical evolution or coupled thermo-hydro-mechanics, into quasi-static, of a structure into nonlinear.

Non-linearity is related either to the behavior of material (for example plastic), or with the geometry (for example in great displacements) or with contact-friction. To have details on the method of resolution employed, one will refer to the reference material [R5.03.01].

The evolution can be studied in several successive work (D-entering concept), either in continuation (the calculated last moment is the initial moment of following calculation), or recovery some on the basis of one former moment.

If the time necessary to carry out calculation is not sufficient, the program stops, but the already calculated results are saved if a database were defined in the profile of study of the user. Product a structure of data of the type `evol_noli`.

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2   Syntax

```
statnl [evol_noli] = STAT_NON_LINE
(   RESULT          =  statnl,                      [evol_noli]

♦   MODEL           =  Mo,                          [model]

♦   CHAM_MATER      =  chmat,                       [cham_mater]

◊   CARA_ELEM       =  carac,                       [cara_elem]

◊   EXCIT           =  _F (
    ♦   LOAD        =  chi,                         [char_meca]
        FONC_MULT   =  fi,                          [fonc/formula]
        TYPE_CHARGE =  /'FIXE_CSTE'                 [DEFECT]
                       /'FIXE_PILO'
                       /'SUIV_PILO'
                       /'SUIV'
                       /'DIDI'
                    ),

◊   CONTACT         =  contact,                     [char_contact]

◊   SOUS_STRUC      =  _F (
    ♦   CAS_CHARGE  =  chi,                         [char_meca]
    ♦   /TOUT       =  'YES',                       [DEFECT]
        /SUPER_MAILLE =  lma,                       [l_maille]
        FONC_MULT   =  fmult,
                    ),

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

◊   ETAT_INIT       =  _F (
    ♦   /|SIGM      =  sig,                         [cham_elem]
         |VARI      =  vain,                        [cham_elem]
         |DEPL      =  depl,                        [cham_no]
         |STRX      =  strx,                        [cham_elem]
         |COHE      =  cohe,                        [cham_elem]
        /EVOL_NOLI  =  evol,                        [evol_noli]
        /NUME_ORDRE =  nuini,                       [I]
        /INST       =  instini,                     [R]
    ◊   PRECISION   =  /1.0E-3,                     [DEFECT]
                       /prec,                       [R]
    ◊   CRITERION   =  /'RELATIVE',                 [DEFECT]
                        /'ABSOLUTE',
    ◊   NUME_DIDI   =  nudidi,                      [I]
    ◊   INST_ETAT_INIT  = istetaini                 [R]
                    ),

♦   INCREMENT       =  _F (
    ♦   LIST_INST       = /litpsr8,                 [listr8]
                          /litps,                   [list_inst]

        /NUME_INST_INIT = nuini,                    [I]
        /INST_INIT      = instini,                  [R]
        /NUME_INST_FIN  = nufin,                    [I]
        /INST_FIN       = instfin,                  [R]
```

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```
               PRECISION        =  /1.0E-3,                    [DEFECT]
                                   /prec,                      [R]

                                   ),

    ◊  CRIT_QUALITE    =  _F (
       ◊  /ERRE_TEMPS_THM  =  /'NOT'                           [DEFECT]
                           =  /'YES'
                              ),

    ◊  METHOD       =  /'NEWTON',                              [DEFECT]
                       /'IMPLEX',
                       /'NEWTON_KRYLOV',
                       /'MODELE_REDUIT',

    ◊  NEWTON         =  _F (
          PREDICTION        =  /'TANGENT',                     [DEFECT]
                               /'ELASTIC',
                               /'EXTRAPOLATES',
                               /'DEPL_CALCULE',
          EVOL_NOLI       =  evol_noli,                        [evol_noli]
          MATRIX       =  /'TANGENT',                          [DEFECT]
                          /'ELASTIC'
          REAC_INCR       =  /1,                               [DEFECT]
                             /mf,                              [I]
          REAC_ITER       =  /1,                               [DEFECT]
                             /it,                              [I]
          REAC_ITER_ELAS  =  /0,                               [DEFECT]
                             /it,                              [I]
          PAS_MINI_ELAS   =  /0,                               [DEFECT]
                             /pasmini,                         [R]
          MATR_RIGI_SYME  =  /'NOT'                            [DEFECT]
                          =  /'YES'
                             ),
    ◊  MODELE_REDUIT    =  _F (
       ◊   PREDICTION  =  /'TANGENT',                          [DEFECT]
                          /'ELASTIC',
                          /'EXTRAPOLATES',
                          /'DEPL_CALCULE',
       ◊   MATRIX    =  /'TANGENT'
                        /'ELASTIC'
       ◊   REAC_INCR   =  /1                                   [DEFECT]
                          /mf
       ◊   REAC_ITER   =  /1                                   [DEFECT]
                          /it
       ♦   BASE_PRIMAL  =  mode_empi
       ◊   DOMAINE_REDUIT  =  /'NOT'                           [DEFECT]
                             /'YES'
       If DOMAINE_REDUIT = 'YES'
            ♦   GROUP_NO_INTERF     = grno
            ◊   CORR_COMPLET      = /'NOT'                     [DEFECT]
                                    /'YES'
       If CORR_COMPLET = 'YES'
            ♦   GROUP_NO_ENCASTRE   = grno
             ◊  COEF_PENA          = /1.0E 6 ,
[DEFECT]
                                     /coef_pena               [R]
    ◊  RECH_LINEAIRE   =  _F (
          METHOD       =  /'CORD'                              [DEFECT]
```

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```
                            /'MIXED'
                            /'PILOTING'
            RESI_LINE_RELA = /1.E-1,                      [DEFECT]
                            /reslin,                      [R]
            ITER_LINE_MAXI = /3                           [DEFECT]
                            /itelin                       [I]
            RHO_MIN        = /1.E-2                        [DEFECT]
                            /rmin                         [R]
            RHO_MAX        = /1.E +1                            [DEFECT]
                            /rmax                         [R]
            RHO_EXCL       = /9.E-3                        [DEFECT]
                            /rexc                         [R]
                          ),

    ◊   PILOTING       =   _F (
        ♦   TYPE        =   /'DDL_IMPO',
                            /'SAUT_IMPO',
                            /'LONG_ARC',
                            /'SAUT_LONG_ARC'
                            /'ANA_LIM',
                            /'DEFORMATION',
                            /'PRED_ELAS',
            ALL         =   'YES',                        [DEFECT]
             /GROUP_MA       =   lgrma,                   [l_gr_maille]
            / MESH       =   lma,                    [l_maille]
             /NOEUD         =   No,                       [node]
            /GROUP_NO    =   rno,                    [gr_noeud]
             CRACK       =   fiss,                  [sd_fiss_xfem]
            NOM_CMP      =   nomcmp,                 [KN]
            /DIRE_PILO   =   direpilo,               [KN]
            COEF_MULT    =   /1. ,                        [DEFECT]

                             /cmult,                      [R]
            ETA_PILO_R_MAX =   etarmax,                   [R]
            ETA_PILO_R_MIN =   etarmin,                   [R]
            ETA_PILO_MAX =   etamax,                      [R]
            ETA_PILO_MIN =   etamin                       [R]
            PROJ_BORNES  =   /'YES'                       [DEFECT]
                            /'NOT'
            EVOL_PARA    =   /'WITHOUT'                        [DEFECT]
                            /'DECREASING'
                            /'GROWING'
            SELECTION    =   /'NORM_INCR_DEPL',            [DEFECT]
                            /'ANGL_INCR_DEPL',
                            /'RESIDUE',
                          ),


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


    ◊   CONVERGENCE    =   _F (
            /RESI_GLOB_RELA =  1.E-6,                     [DEFECT]
             / | RESI_GLOB_MAXI =   resmax,               [R]
             | RESI_GLOB_RELA  =   resrel,                [R]
             | RESI_COMP_RELA  =   rescmp,                [R]
             | RESI_REFE_RELA  =   resref,                [R]
            SIGM_REFE    =   sigref,                      [R]
            EPSI_REFE    =   sigref,                      [R]
            DEPL_REFE    =   depref,                      [R]
            EFFORT_REFE  =   forref,                      [R]
```

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```
                MOMENT_REFE      =   momref,                     [R]
                VARI_REFE        =   varref,                     [R]
                FLUX_THER_REFE   =   sigref,                     [R]
                FLUX_HYD1_REFE   =   sigref,                     [R]
                FLUX_HYD2_REFE   =   sigref,                     [R]
                ITER_GLOB_ELAS   = /25,                          [DEFECT]
                                   /maxelas,                     [I]
                ITER_GLOB_MAXI   = /10,                          [DEFECT]
                                   /maglob,                      [I]
                STOP             = /'YES',                       [DEFECT]
                                    /'NOT',
                               ),

    ◊   CRIT_STAB        = _F (

        TYPE             = /'BUCKLING'                           [DEFECT]
                         = /'STABILITY'
        OPTION           = /' PLUS_PETITE ',                     [DEFECT]
                           /'BAND',
                           /'CALIBRATION',
          If OPTION=' PLUS_PETITE'
          {
             ◊   NMAX_CRIT       = /3,                           [DEFECT]
                                   /nbcrit,                      [I]
          }
          If OPTION=' BANDE'
          {
             ◊   CHAR_CRIT       =  intba ,                      [listr8]
          }
          If OPTION=' CALIBRATION'
          {
             ◊   CHAR_CRIT       =  intba ,                      [listr8]
        }
        COEF_DIM_ESPACE  = /5,                                   [DEFECT]
                           /coef,                                [I]
        RIGI_GEOM        = /'YES',                               [DEFECT]
                         = /'NOT',
        MODI_RIGI        = /'NOT',                               [DEFECT]
                         = /'YES',
        DDL_EXCLUS       = list1_ddl
         DDL_STAB        = list2_ddl
        /LIST_INST       = list_r8,                              [listr8]
        /INST            = l_r8,                                 [R]
        /PAS_CALC        = npas,                                 [I]
        ◊   PRECISION    = /1.E-6,                               [DEFECT]
                           /prec,                                [R]
            ◊    CRITERION   =  /'RELATIVE',                     [DEFECT]
                               /'ABSOLUTE',
        SIGN             = /'POSITIF_NEGATIF',                   [DEFECT]
                         = /'POSITIVE',
                         = /'NEGATIVE',
        PREC_INSTAB      = /1.E-6,                               [DEFECT]
                           /prec_instab,                         [R]
                         ),


    ◊   ENERGY       =  _F ()

    ◊   SCHEMA_THM       =  _F (
        ◊   PARM_THETA =    1.0 ,                                [DEFECT]
```

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```
                                    parm_theta ,                     [R]
          ◊   PARM_ALPHA  =    1.0 ,                                 [DEFECT]
                                    parm_alpha ,                     [R]
                            ),

     ◊  FILING          = _F (
          /LIST_INST       =  list_r8,                              [listr8]
          /INST            =  l_r8,                                 [R]
          /PAS_ARCH        =  npas,                                 [I]
          ◊   PRECISION    =  /1.E-6,                               [DEFECT]
                                /prec,                              [R]
          ◊    CRITERION   =  /'RELATIVE',                          [DEFECT]
                                /'ABSOLUTE',
          ◊    CHAM_EXCLU  =    list_txt,
                            ),

     ◊  POSTING          = _F (
          ◊   UNIT         =  /unite                                [I]
          ◊   INFO_RESIDU  =  /'NOT',                               [DEFECT]
                                /'YES'
          ◊   INFO_TEMPS   =  /'NOT',                               [DEFECT]
                                /'YES'
                            ),
     ◊  MEASUREMENT            =  _F (
          ◊   TABLE        =  /'NOT',                               [DEFECT]
                                /'YES'
          ◊   UNIT         = links
                            ),
     ◊  HHO              = _F (
          ◊   OPTIMIZATION  =/'MEMORY',                             [DEFECT]
                                /'TIME'
          ◊    STABILIZATION = /'CAR',                              [DEFECT]
                              / ' HANDBOOK '
          {If STABILIZATION= 'HANDBOOK'
               ◊   COEF_STAB     =  coeff                           [R]
          }
     ◊  OBSERVATION     =   _F (
          ◊   TITLE       =  title,                                 [list_k]
          ♦  NOM_CHAM     =  |' DEPL',
                              |' VITE',
                              |' ACCE',
                              |' DEPL_ABSOLU',
                              |' VITE_ABSOLU',
                              |' ACCE_ABSOLU',
                              |' SIEF_ELGA',
                              |' VARI_ELGA',
                              |' FORC_NODA',
                              |' CONT_NOEU',
                              |' CONT_ELEM',
          ◊   EVAL_CHAM    =  /'VALE',                              [DEFECT]
                                /'MIN',
                                /'MAX',
                                /'MOY',
                                /'MINI_ABS',
                                /'MAXI_ABS',
          ◊   NOM_CMP      =  lnocmp ,                              [l_Kn]
          ◊   NOM_VARI     =  lnovari   ,                           [l_Kn]
          ◊   EVAL_CMP     =  /'VALE',                              [DEFECT]
                                /'FORMULA',
```

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```
                {If EVAL_CMP=' FORMULE'
                   ◊   FORMULA     =   forms                   [formule_aster]
                 }
                {If CHAM is of type ELGA   (SIEF_ELGA, VARI_ELGA)
                   ◊   ALL         =   'YES',                  [DEFECT]
                   ◊   /GROUP_MA   =   lgrma,                  [l_gr_maille]
                   ◊   / MESH      =   lma,                    [l_maille]
                   ◊   EVAL_ELGA   =   /'VALE',                [DEFECT]
                                       /'MIN',
                                       /'MAX',
                   {If EVAL_ELGA = ' VALE'
                        ♦ NOT        =   pi ,                  [I]
                        ◊ SOUS_POINT    =   spi ,              [I]
                   }
                }
                {If CHAM is of type ELEM   (CONT_ELEM)
                   ◊   ALL         =   'YES',                  [DEFECT]
                   ◊   /GROUP_MA   =   lgrma,                  [l_gr_maille]
                    ◊  / MESH      =   lma,                    [l_maille]
                }
                {If CHAM is of type NOEU
                   ◊   ALL         =   'YES',                  [DEFECT]
                   ◊   /GROUP_MA   =   lgrma,                  [l_gr_maille]
                   ◊   / MESH      =   lma,                    [l_maille]
                   ◊   /NOEUD      =   No,                     [node]
                   ◊   /GROUP_NO   =   rno,                    [gr_noeud]
                 }
                ◊ /'OBSE_ETAT_INIT' =/'YES',                  [DEFECT]
                                     /'NOT'
                ◊ /LIST_INST    =   linst,                    [listr8]
                ◊ /INST         =   linst,                    [l_R]
                ◊ /PAS_OBSE     =   not ,                     [I]
                ◊   CRITERION   =   /'RELATIVE',              [DEFECT]
                                    /'ABSOLUTE',
                { If  CRITERION  =   'RELATIVE'
                   ◊ PRECISION  =   /1.0E-6,                  [DEFECT]
                                    /prec,                    [R]
                }
                { If  CRITERION  =   'ABSOLUTE'
                   ♦ PRECISION  =   prec,                     [R]
                }
              ),
        ◊  SUIVI_DDL        =   _F (
              ◊   TITLE       =   title,                      [list_k]
              ♦   NOM_CHAM    =   |' DEPL',
                                  |' VITE',
                                  |' ACCE',
                                  |' SIEF_ELGA',
                                  |' VARI_ELGA',
                                  |' FORC_NODA',

              ◊   EVAL_CHAM   =   /'VALE',                    [DEFECT]
                                  /'MIN',
                                  /'MAX',
                                  /'MOY',
                                  / 'MINI_ABS',
                                  /'MAXI_ABS',
              ◊   NOM_CMP     =   lnocmp ,                    [l_Kn]
              ◊   NOM_VARI    =   lnovari   ,                 [l_Kn]
```

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```
              ◊   EVAL_CMP     =  /'VALE',                      [DEFECT]
                                 /'FORMULA',
            {If EVAL_CMP=' FORMULE'
                 ◊   FORMULA     =    forms
   [formule_aster]
                 }
            {If CHAM is of type ELGA    (SIEF_ELGA, VARI_ELGA)
                 ◊     ALL      =   'YES',                      [DEFECT]
                  ◊  /GROUP_MA      =  lgrma,
        [l_gr_maille]
                  ◊  / MESH       =  lma,                       [l_maille]
                 ◊   EVAL_ELGA    =  /'VALE',                   [DEFECT]
                                   /'MIN',
                                   /'MAX',
              {If EVAL_ELGA = ' VALE'
                   ♦  NOT        =  pi ,                    [I]
                    ◊  SOUS_POINT     =  spi,               [I]
              }
            }
            {If CHAM is of type NOEU
                 ◊     ALL      =   'YES',                      [DEFECT]
                 ◊   /GROUP_MA    =  lgrma,
        [l_gr_maille]
                  ◊  / MESH       =  lma,                    [l_maille]
                  ◊  /NOEUD      =   No,                       [node]
                  ◊  /GROUP_NO    =  rno,                  [gr_noeud]
             }
        ),
    ◊  INFORMATION           =  /1,
       [DEFECT]
                         /2,
    ◊  TITLE            =  tx                         [KN]
    );
```

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3 Operands

3.1 Keyword RESULT

If one wishes to continue a calculation already carried out, RESULT indicate which object is enriched (see too ETAT_INIT).

3.2 Operands MODEL / CHAM_MATER / CARA_ELEM

♦ MODEL = Mo

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

♦ CHAM_MATER = chmat

Name of the affected material field on the model Mo. Attention, all the principal meshs of the model must be associated with a material (if not fatal error with not very explicit message),

◊ CARA_ELEM = carac

Name of the characteristics (carac) elements of hull, beam, pipe, bars, cable, and discrete elements affected on the model Mo. Obviously, this keyword is optional: if the model does not contain such elements, it is not useful; on the other hand, if the model contains such elements, it is obligatory.

3.3 Keyword EXCIT

◊ EXCIT=_F ()

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

3.3.1 Operands LOAD

♦ LOAD = ch_i

ch_i is the mechanical loading (possibly comprising the evolution of a field of temperature) specified with i ᵉᵐᵉ occurrence of EXCIT.

Note:
1) *In a thermomechanical calculation, if the initial temperature is different from the temperature of reference (given in the operator AFFE_MATERIAU), the field of deformation associated with the initial moment can be incompatible and thus lead to a state of stresses and internal variables associated not no one. If an incremental relation of behavior is used and if one explicitly does not define a state of stresses and internal variables initial (associate with a field of initial temperature different from the temperature of reference), the internal variable and stress field calculated with the first increment will take account only of the only temperature variation between the initial moment and the first moment, and not of the possible constraints of compatibility associated with the initial temperature. To take this initial state hopes some, it should be given explicitly, for example thanks to the keywords SIGM, DEPL, VARI in ETAT_INIT . **To avoid such situations which can lead to miscalculations, it is to better begin a calculation by considering that it is necessary to start from a virgin state.***
2) If one carries out a calculation into axisymmetric and that one imposes nodal forces, these efforts must be divided by 2π (one works on a sector of a radian) compared to the real loadings. In the same way, if one wishes to calculate the resultant of the efforts, the result is to be multiplied by 2π to have the total resultant on the complete structure. In the same way in plane

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constraints or plane deformation, one works on a thickness unit: the efforts (on the thickness) applied must be divided by the thickness, the real efforts are obtained by multiplying by the thickness the efforts "of calculation".

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3.3.2   Operand **FONC_MULT**

◊   FONC_MULT = f_i

f_i is the multiplying function of the time of the loading specified with $I^{ème}$ occurrence of EXCIT.

The loading and boundary conditions for n occurrences of the keyword factor EXCIT are:

$$ch = \sum_{i=1}^{n} f_i . ch_i$$

For the conditions of Dirichlet, of course, only the specified value is multiplied by f_i.

By default: $f_i = 1$.

3.3.3   Operand **TYPE_CHARGE**

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

By default, TYPE_CHARGE is worth 'FIXE_CSTE' : that corresponds to a loading applied to the initial geometry and not controlled. It can however be a function, and, in particular, to depend on time.

If TYPE_CHARGE is worth 'FIXE_PILO', the loading is always fixed (independent of the geometry) but will be controlled thanks to the keyword PILOTING [§3.15]. The loads controllable must result from the operator AFFE_CHAR_MECA or AFFE_CHAR_MECA_F (if it is not a function depending on time) and not to be affected keyword FONC_MULT. One cannot control the loadings of gravity, the centrifugal force, the forces of Laplace, the loadings thermal or of initial or unelastic deformations, and the conditions of connection.

To have controlled loads dependent on geometry (loads known as "following"), one has TYPE_CHARGE who is worth 'SUIV_PILO'.

A fixed loading is revalued only at each new moment, and only if CH_I depends on time (defined in AFFE_CHAR_MECA_F and parameterized by the moment or affected by FONC_MULT).

If TYPE_CHARGE is worth 'SUIV', the loading is known as "follower", i.e. it depends on the value of the unknown factors: for example, the pressure, being a loading applying in the normal direction to a structure, depends on the geometry brought up to date of this one, and thus on displacements. A following loading is revalued with each iteration of the algorithm of resolution. Currently the loadings which can be described as follower are the loading of gravity for the element of CABLE_POULIE, pressure for modelings 3D, 3D_SI, D_PLAN, D_PLAN_SI, AXIS, AXIS_SI, C_PLAN, C_PLAN_SI and for all modelings THM (3D_HHM*, 3D_HM*, 3D_JOINT_CT, 3D_THH*, 3D_THHM*, 3D_THM*, AXIS_HHM*, AXIS_HM*, AXIS_THH*, AXIS_THHM*, AXIS_THM*, D_PLAN_HHM*, D_PLAN_HM*, D_PLAN_THH*, D_PLAN_THHM*, D_PLAN_THM*) and the centrifugal force in great displacements (keyword ROTATION in AFFE_CHAR_MECA). One can also impose that a loading of Dirichlet is following in the case of the rigidification of part of the structure by the use of LIAISON_SOLIDE (see [U4.44.01]) in great transformations.

Note:

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- *The pressure can be defined by a function depending on the geometry (AFFE_CHAR_MECA_F). In the following case, one can choose if this dependence is done compared to the initial geometry with the parameters X , Y , and Z of DEFI_FONCTION or compared to the geometry reactualized with the parameters XF , YF , and ZF .*
- *The loading of the type LIAISON_SOLIDE follower is strictly incompatible with piloting and linear research. He is usable only with isoparametric finite elements 2D and 3D (not with the elements of structures such as beam, plates and hulls).*

If TYPE_CHARGE is worth 'DIDI' then the conditions of Dirichlet (imposed displacements, linear conditions) will apply to the increment of displacement as from the moment given under ETAT_INIT/NUMÉRIQUE_DIDI (by default the moment of resumption of calculation) and not on total displacement. For example for a displacement imposed (keyword DDL_IMPO of the operator AFFE_CHAR_MECA) the condition will be form $u - u_0 = d$ where u_0 is the displacement defined by NUME_DIDI and not $u = d$.

3.4 Keyword CONTACT

♦ CONTACT = contact

This simple keyword makes it possible to activate the resolution of contact-friction or the taking into account of a unilateral connection. contact is a concept resulting from the operator DEFI_CONTACT [U4.44.11].

Caution:

This simple keyword accepts one concept. One cannot thus mix in the same non-linear calculation the resolution of the contact and the taking into account of a unilateral connection. One cannot mix the various formulations either (DISCRETE, CONTINUOUS and XFEM)

3.5 Keyword SOUS_STRUC

◊ SOUS_STRUC

This keyword factor makes it possible to specify which are the loadings to be used for under - static structures which then are obligatorily part of the model. In its absence, the loadings on under structures are worthless.

These loadings are added to the loadings "finite elements" which can be applied to the rest of the model. For more precision concerning the use of substructures (elastic linear) in a non-linear structure, one will refer to documentation [U2.07.02] and the CAS-test ssnv193a.

3.5.1 Operand CAS_CHARGE

♦ CAS_CHARGE = nocas

nocas is the name of the loading case to be used. See operator MACR_ELEM_STAT [U4.62.01].

3.5.2 Operands ALL/SUPER_MAILLE

♦ /TOUT = 'YES'

This keyword makes it possible to affect the loading nocas with all the substructures of the model.

/SUPER_MAILLE = l_mail

This keyword factor makes it possible not to affect the loading nocas that with some under - structures.

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3.5.3 Operand FONC_MULT

◊ FONC_MULT = f_i

f_i is the multiplying function of the time of the loading specified with I^ème occurrence of SOUS_STRUCT.
The behavior of this keyword is the same one as for its occurrence in EXCIT.

3.6 Keyword BEHAVIOR

The syntax of this keyword common to several orders is described in the document [U4.51.11].

3.7 Keyword SCHEMA_THM

◊   PARM_THETA   =   1.0 ,   [DEFECT]
                         parm_theta ,   [R]
◊   PARM_ALPHA   =   1.0 ,   [DEFECT]
                         parm_alpha ,   [R]

This keyword makes it possible to manage the parameters of diagrams THM for hydraulics (PARM_THETA, to see [R7.01.10]) and for finished volumes of SUSHI type (PARM_ALPHA, to see [R7.01.34]).

Note: parameter PARM_THETA is quite distinct from that defined in the keyword BEHAVIOR (see §).

3.8 Keyword ETAT_INIT

◊   **ETAT_INIT**

This keyword makes it possible to define an initial state of reference. By defaults, all the fields are identically worthless. The initial state can be defined either by specifying each field of the initial state, or in extraction since a concept of the type evol_noli preexistent.

Note:

- *If the user specified that the concept result is réentrant (by the reserved word reuse), the keyword ETAT_INIT is obligatory.*
- *If one uses the method continues contact, the resumption of calculation automatically takes into account the states of contact and the thresholds of friction resulting from preceding calculation.*

If one uses an initial state which it MODEL is different from MODEL of calculation indicated in the operator, Code_Aster proceeds automatically on the way between the two models:
- If the model of calculation is included in the model given in the initial state, the data of the initial state are simply recopied mesh with mesh for all the fields;
- If the model given in the initial state is included in the model of calculation, Code_Aster starts by copying the values of the initial state for the common meshs then complete with the zero value;
In the last case, it is necessary to take care of the direction which an initial worthless internal variable in calculation can have.

In great deformations, the user wishing to use the formalism GDEF_LOG with an initial stress field (ETAT_INIT) will refer to the case test SSNP159B. Indeed, to impose one initial stress field, the user must give as starter the tensor of constraint defined in space logarithmic curve T (and not that of Cauchy σ). The components of this last being stored as internal variables, the operands

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should be used VARI and DEPL described below (these fields can for example be obtained by the order CREA_CHAMP [U4.72.04]).

If the characteristic materials strongly depend on the variables of order, it is advisable to be careful on the selection of the initial state, with the risk not to converge. Indeed, elastic behaviors (ELAS_*) exist in two versions (see [U4.51.11]). The elastic version "pure" is automatically selected by the code when there is no initial state, if not, the incremental version is selected. However, only the latter is effective if there are strong variations of characteristic materials (elastic in this case) compared to the variables of order.

Note:

> *If calculation has difficulty converging in this case, simplest to create a state of initial stresses artificially no one is to force the selection of the incremental mode, or to use a purely elastic matrix (operand NEWTON), which allows an unquestionable convergence at the cost of a large number of iterations.*

3.8.1 Operands SIGM/VARI/DEPL/STRX

```
♦   /  |   SIGM = sig
       |   VARI = vain
       |   DEPL = depl
       |   STRX = strx
       |   COHE = cohe
```

sig is it stress field at the points of Gauss, vain is the field of internal variables at the points of Gauss and depl is the field displacements with the nodes taken in an initial state and strx is the field of efforts and displacements corresponding to the elements of structures. The field cohe is the field of cohesive internal variables of the law CZM_LIN_MIX in the case of a calculation XFEM: its structure, particular, justifies the use of a keyword distinct from VARI. SI one of these fields is not specified, it is taken null by default. They can for example result from the order CREA_CHAMP, or to be read in a file by the order LIRE_RESU.

3.8.2 Operands EVOL_NOLI

/ EVOL_NOLI = evol

Name of the concept of the type evol_noli from where will be extracted the initial state.

3.8.3 Operand NUME_ORDRE/INST / NUME_DIDI

◊ / NUME_ORDRE = nuini
 / INST   = instini

Extraction of the initial mechanical state in evol starting from the number of filing NUME_ORDRE or of the moment of filing INST to carry out the continuation of calculation.
If NUME_ORDRE or INST are not filled, one takes the last existing number filed in evol.

◊ NUME_DIDI   = nudidi

In the case of loadings of differential the Dirichlet type ('DIDI'), one gives under NUME_DIDI the number of filing of the mechanical state (displacements) which is used as reference for the application of these boundary conditions. By default one takes the definite mechanical state under NUME_ORDRE or INST.

3.8.4 Operand INST_ETAT_INIT

◊   INST_ETAT_INIT = istetaini

One can associate a value of moment istetaini in this initial state.
By default:

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1) When the initial state is defined by the data of the fields (ETAT_INIT with DEPL/SIGM/VARI), an associated moment ago.

2) When the state is given by a concept evol_noli (ETAT_INIT with EVOL_NOLI), it is the moment in preceding calculation (istetaini = instini).

A - Simple example (behavior by default)

```
LIST1    = DEFI_LIST_REEL (=0 BEGINNING. ,
                            INTERVAL =_F (UNTIL = 4. , =4 NUMBER)),

U        = STAT_NON_LINE (INCREMENT =_F (LIST_INST =LISTE1)) ,

LIST2    = DEFI_LIST_REEL (=4 BEGINNING. ,
                            INTERVAL =_F (UNTIL = 10. , =6 NUMBER)),

U        = STAT_NON_LINE (reuse=U,
                          INCREMENT =_F (LIST_INST =LISTE2),
                          ETAT_INIT =_F (EVOL_NOLI =U)) ,
```

First STAT_NON_LINE : carry out calculation for the moments 1 , 2 , 3 and $4s$.
Second STAT_NON_LINE : carry out calculation for the moments 5 , 6 , 7 , 8 , 9 and $10s$, the initial state corresponding to time $4s$.

B - Example to show the interest of INST_ETAT_INIT (two different lists of moments)

```
LIST1    = DEFI_LIST_REEL (=0 BEGINNING. ,
                            INTERVAL =_F (UNTIL = 10. , =10 NUMBER)),

U        = STAT_NON_LINE (INCREMENT =_F (LIST_INST =LISTE1)) ,

LIST2    = DEFI_LIST_REEL (=20 BEGINNING. ,
                            INTERVAL =_F (UNTIL = 30. , =10 NUMBER)),

U        = STAT_NON_LINE (reuse=U
                          INCREMENT =_F (LIST_INST =LISTE2),
                          ETAT_INIT =_F (EVOL_NOLI =U,
                          INST_ETAT_INIT = 20.)) ,
```

First STAT_NON_LINE : carry out the calculation of the moments 1 with $10s$.
Second STAT_NON_LINE : carry out the calculation of the moments 21 with $30s$, the initial state corresponding to the moment $t=10s$ first STAT_NON_LINE (by default INST=10.). This initial state corresponds for this second STAT_NON_LINE at the moment $t=20s$. (INST_ETAT_INIT=20.).

C - Example to show the interest of INST_ETAT_INIT (practical when the cyclic one is made)

```
LIST1    = DEFI_LIST_REEL (=0 BEGINNING. ,
                            INTERVAL =_F (UNTIL = 10. , =10 NUMBER)),

U1       = STAT_NON_LINE (INCREMENT =_F (   LIST_INST =LISTE1)) ,

U2       = STAT_NON_LINE (INCREMENT =_F (   LIST_INST =LISTE1),
                          ETAT_INIT =_F (   EVOL_NOLI =U1,
                               INST_ETAT_INIT = 0.)) ,
```

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First STAT_NON_LINE: carry out the calculation of the moments 1 with $10s$.

Second STAT_NON_LINE: carry out the calculation of the moments 1 with $10s$, the initial state corresponding to the moment $t=10s$ first STAT_NON_LINE (by default INST=10.). This initial state corresponds for this second STAT_NON_LINE at the moment $t=0s$. (INST_ETAT_INIT= 0.).

3.8.5 Operand PRECISION/CRITERION

◊   PRECISION = prec

Confer [U4.71.00] for detailed syntax
This parameter is used to locate the right number of order (NUME_ORDRE) when the user informs the moment (INST). Indeed, moments in STAT_NON_LINE are located by a sequence number (an entirety). If the user wants to use one moment (a reality) and not a sequence number for INST, the operand precision makes it possible to select this sequence number.
Example:

Digital	1	2	3	4	5	6	7
INST	0,0010	0,0020	0,0030	0,0040	0,0050	0,0060	0,0070

If the user wants to select the moment corresponding to NUMÉRIQUE=4, it is enough for him to say INST=0,004. By   against, for the second example:

Digital	1	2	3	4	5	6	7
INST	0,10000001	0,10000002	0,10000003	0,10000004	0,10000005	0,10000006	0,10000007

If the user wants to select the moment corresponding to NUMÉRIQUE=4, it is not enough for him to say   INST=0,10000004, because the relative difference between the moments is worth $\frac{0,10000005-0,10000004}{0,10000004}=1\text{E-}7$ who is higher than the value of precision by default ($1\text{E-}6$). One will not be able to thus distinguish   NUMÉRIQUE=3,4 and 5 (the code stops then in fatal error). It is then enough to change the parameter   PRECISION to be able to select the moment (in the example, PRECISION=1E-8 will be appropriate).

3.9   Keyword INCREMENT

♦   INCREMENT=_F ()

Defines the time intervals taken in the incremental method.

The moments thus defined have physical direction only for relations of behavior where time intervenes explicitly (viscoelastic or viscoplastic for example). In the other cases, they allow only indicer the increments of load and to parameterize the evolution of a possible field of temperature.

3.9.1   Operand LIST_INST

♦ LIST_INST = /litpsr8,   [listr8]
                /litps,   [list_inst]

♦   If LIST_INST = litpsr8   [listr8]

The moments of calculation are those defined in the concept litpsr8 by the operator DEFI_LIST_REEL [U4.34.01].

♦   If LIST_INST = litps   [list_inst]

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The moments of calculation are those defined in the concept litps by the operator DEFI_LIST_INST [U4.34.03].

3.9.2 Operands NUME_INST_INIT/ INST_INIT / NUME_INST_FIN/ INST_FIN

```
/NUME_INST_INIT  =   nuini
/INST_INIT       =   instini
```

The initial moment of the calculation (which thus (Re) is not calculated) is indicated either by its value (INST_INIT), that is to say by its sequence number in the list of moments litps (NUME_INST_INIT). To be able to reach by value, it is necessary that the list is ordered.

In the absence of keywords INST_INIT or NUME_INST_INIT, the defect is calculated in the following way:

1) If an initial state is specified (operand ETAT_INIT) and if it defines one corresponding moment (by EVOL_NOLI or INST_ETAT_INIT) then the initial moment is that defined by this initial state,

2) If there is no initial state (operand ETAT_INIT absent) or that it does not define a moment corresponding (the fields are given in ETAT_INIT without specifying INST_ETAT_INIT), then one takes the first moment of the list of moments (NUME_INST_INIT=0).

3) In the event of filing (see keyword FILING), the initial moment in continuation is the last step filed and not that defined in INST_INIT.

```
/NUME_INST_FIN   =   nufin
/INST_FIN        =   instfin
```

The final moment (last calculated step) is indicated same manner that the initial moment (either NUME_INST_FIN, that is to say INST_FIN), except that it is not possible to refer to the moment of the initial state.

Caution:
- If the automatic recutting of the step of time is activated, NUME_INST_FIN account does not hold any and always works on the list of moments initial. NUME_INST_INIT and NUME_INST_FIN are active only with initialization.
- The list of moments being strictly increasing, it can arrive that some not of time are not filed although not required. For example, in the case of a resumption of calculation. If calculation in recovery of a preceding calculation does not have any moment higher than the first phase of calculation, no step of time will be filed.

A - Simple example (behavior by default)

```
LIST = DEFI_LIST_REEL (=0 BEGINNING. ,
                       INTERVAL =_F (UNTIL = 10. , =10 NUMBER)),
U = STAT_NON_LINE (    INCREMENT =_F ( LIST_INST =LISTE,
                                       INST_FIN =4.)) ,
U = STAT_NON_LINE (    reuse=U,
                       INCREMENT =_F ( LIST_INST =LISTE),
                                       ETAT_INIT = _F (EVOL_NOLI:
U)) ,
```

First STAT_NON_LINE: carry out calculation for the moments 1, 2, 3 and $4s$.

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Second STAT_NON_LINE: carry out calculation for the moments 5, 6, 7, 8, 9 and 10s, the initial state corresponding to time 4s . (by default INST_INIT=INST_ETAT_INIT=INST=4.).

B - Example to show the interest of INST_INIT

```
LIST = DEFI_LIST_REEL (=0 BEGINNING. ,
                          INTERVAL = _F (UNTIL = 10. , =10 NUMBER)),

U = STAT_NON_LINE   (  INCREMENT = _F ( LIST_INST  = LIST,
                                        INST_FIN  = 4.)) ,
U = STAT_NON_LINE   (  reuse = U,
                       INCREMENT = _F ( LIST_INST =LISTE,
                                        INST_INIT =8.),
                       ETAT_INIT = _F (
EVOL_NOLI =U)) ,
```

First STAT_NON_LINE: carry out the calculation of the moments 1 with 4s .

Second STAT_NON_LINE: carry out calculation for the moments 9 and 10s (does not do anything for $t = 5,6,7$ and 8s), the initial state corresponding to time $t = 4$s (by default INST=4.).

3.9.3 Operand PRECISION

◊   PRECISION = prec

Cf. [U4.71.00] for detailed syntax

This   parameter   is   used   to   locate   the   right   number   of   order (NUME_INST_FIN/NUMÉRIQUE_INST_INIT) when the   user   informs   the   moment (INST_FIN/INST_INIT). Indeed, moments in STAT_NON_LINE are located by a sequence number (an entirety). If the user wants to use one moment (a reality) and not one   sequence   number   for (NUME_INST_*), the operand precision makes it possible to select this sequence number.
Example:

Digital	1	2	3	4	5	6	7
INST	0,0010	0,0020	0,0030	0,0040	0,0050	0,0060	0,0070

If the user wants to select the moment corresponding to NUMÉRIQUE=4, it is enough for him to say INST=0,10000004. By   against, for the second example:

Digital	1	2	3	4	5	6	7
INST	0,10000001	0,10000002	0,10000003	0,10000004	0,10000005	0,10000006	0,10000007

If the user wants to select the moment corresponding to NUMÉRIQUE=4, it is not enough for him to say   INST=0,10000004,   because   the   relative   difference   between   the   moments   is   worth $\dfrac{0,10000005 - 0,10000004}{0,10000004} = 1E\text{-}7$ who is higher than the value of precision by default ($1E\text{-}6$). One will not be able to thus distinguish   NUMÉRIQUE=3,4 and 5 (the code stops then in fatal error). It is then enough to change the parameter   PRECISION to be able to select the moment (in the example, PRECISION=1E-8 will be appropriate).

3.10 Operand CRIT_QUALITE

◊   **ERRE_TEMPS_THM =   /'NOT'   [DEFECT]**

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/ 'YES'

This operand makes it possible to activate the calculation of the indicators of error.
ERRE_TEMPS_THM is the temporal indicator of error for non stationary modelings HM. See
[R4.10.05].

3.11 Operand METHOD

◊   METHOD = / 'NEWTON'
               / 'IMPLEX'
               / 'NEWTON_KRYLOV'
               / 'MODELE_REDUIT'

Allows to choose the method of resolution of the nonlinear incremental problem.

/ 'NEWTON'

One uses the algorithm of Newton-Raphson to solve the problem (see [R5.03.01]).

/ 'IMPLEX'

The algorithm is used IMPLEX to solve the problem (see [R5.03.81]).

/ 'NEWTON_KRYLOV'

One uses an inaccurate version of the algorithm of Newton-Raphson; the precision of the
resolutions of systems linear by an iterative method is adapted during each step of loading (see
[R5.03.01]).

/ 'MODEL_REDUCED'

One is used method of reduction of model to do the non-linear calculation (see [R5.01.05]). It is
necessary to have built a base to reduce (order beforehand DEFI_BASE_REDUITE).

3.12 Keyword NEWTON

Specify the characteristics of the method of resolution of the non-linear incremental problem
(method of Newton-Raphson)

3.12.1 Operand PREDICTION

◊   PREDICTION = / 'TANGENT'
                 / 'ELASTIC'
                 / 'EXTRAPOLATES'
                 / 'DEPL_CALCULE'

The purpose of the phase of prediction (cf [R5.03.01]) is to calculate an estimate of the field of
displacements in order to make it possible the method of Newton more quickly to converge.
When the keyword is absent, it is the tangent matrix of speed (option RIGI_MECA_TANG) who is
used if one chose for the method of Newton one MATRICE=' TANGENTE', and it is the elastic
matrix (option RIGI_MECA) who is used if one chose MATRICE=' ELASTIQUE'.

/ 'TANGENT'

One uses the tangent matrix of the problem of speed (option RIGI_MECA_TANG).

/ 'ELASTIC'

One uses the elastic matrix (option RIGI_MECA).

/ 'EXTRAPOLATES'

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One calculates the estimate of the increment of displacement starting from the total increment obtained as solution with the step of previous time (balanced by the report of the steps of time). One projects this estimate on the whole of the fields kinematically acceptable (i.e satisfying the boundary conditions with Dirichlet) according to the standard given by the elastic matrix, which must thus be calculated. This functionality is interesting in the case of the use of diagrams of explicit integration local of Runge-Kutta type which do not provide a tangent matrix: in this case the method of Newton uses an elastic matrix, but the iteration count necessary can be high. The use of extrapolation can improve the performances.

/ `DEPL_CALCULE`

Allows to propose like displacement for the prediction with each step of time, the displacement given by a mechanical history specified under the keyword `EVOL_NOLI` (§17). Displacement is project on the whole of the fields kinematically acceptable, as for the method `EXTRAPOLATE`.

Note:
- Methods `EXTRAPOLATES` and `DEPL_CALCULE` carry out a projection of the solution on the whole of the fields kinematically acceptable. One helps oneself for that of the boundary conditions of Dirichlet given in the keyword `EXCIT`. In this case, it is not possible to use loadings of "kinematic" Dirichlet of the type (operand `AFFE_CHAR_CINE`) but only of the loadings of Dirichlet by dualisation (operand `AFFE_CHAR_MECA`). An alarm warns the user if *Code_Aster* would not have found loadings of Dirichlet dualized. The risk in this case being that the field of displacement is not kinematically acceptable;
- It is necessary that the displacements used in `EXTRAPOLATES` and `DEPL_CALCULE` are resulting from calculation using the same grid because the limiting conditions must be coherent;
- Because of this projection on the limiting conditions, these two options are incompatible with the features of `PILOTING` .

Attention, because of impossibility "of correctly projecting" the limiting conditions from one grid to another, it from now on is strongly disadvised using `EXTRAPOLATES` and `DEPL_CALCULE` starting from a grid different from current calculation.

Utility:
- If one obtained a first solution on the same grid with other parameters materials or another behavior, the fields of displacements can be re-used in calculation.
- That makes it possible to reduce the place memory and to preserve these results for a later continuation. For a large calculation, one can store only displacements at every moment with formats IDEAS or MED in `IMPR_RESU`. If one wants to recompute the internal constraints and variables, one does one `LIRE_RESU` with the adequate format then one uses `DEPL_CALCULE` with `ITER_GLOB_MAXI=0` (only one iteration is carried out) and `ARRET=' NON'` (there is not convergence, one does not check balance). It is however necessary for reasons of syntax to give a loading (to avoid the Dirichlet loadings which impose a linear resolution) as well as convergence criteria, even if this information is not taken into account.

3.12.2 OperandS `MATRIX`, `REAC_INCR`, `REAC_ITER`, `PAS_MINI_ELAS` and `REAC_ITER_ELAS`

```
◊   MATRIX   =  / 'TANGENT'
◊   REAC_INCR = /1                   [DEFECT]
                /mf
◊   REAC_ITER = /1                   [DEFECT]
                /it
```

The matrix used for the total iterations of the method is the tangent matrix [R5.03.01]. The tangent matrix of prediction is revalued all them MF increments of time (MF positive or null) and the coherent

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tangent matrix (option `FULL_MECA`) is revalued all them `it` iterations of Newton for an increment of time given (precisely to the iterations of number `it`, `2it`, `3it`...). Thus with the first iteration of Newton, one reassembles the tangent matrix only if `it` 1 is worth: if not one keeps the matrix used in the phase of prediction. By convention if `it` the 0 matrix is worth is not revalued during all the step of time.

◊   PAS_MINI_ELAS = /0.   [DEFECT]
                     /pasmini   [R]
◊   REAC_ITER_ELAS = /0   [DEFECT]
                     /it   [I]

These options make it possible to pass from the tangent matrix to the matrix of discharge (i.e by considering that non-linearities do not evolve) when the step of time is lower than `pasmini`. This matrix of discharge is the elastic matrix for the models of behavior of the plastic type; for the models of damage it is identified with the secant matrix.

As convergence with the elastic matrix is slower than that with the tangent matrix, the keyword `ITER_GLOB_ELAS` under the keyword factor `CONVERGENCE` allows to define an iteration count maximum specific to the use of the matrix elastic and different from that associated with the use of the tangent matrix.

One can define a frequency of reactualization of the matrix of discharge with the keyword `REAC_ITER_ELAS` (analogue of `REAC_ITER`). If the matrix of discharge does not depend on the state of deformation (what is the case for plastic materials but not for the models of damage), to take `REAC_ITER_ELAS = 0` (since it will be the same one during iterations).

Utility:

This option can be useful when the automatic recutting of the step of time is not enough to make converge a calculation. For example, in the case of lenitive laws, the tangent matrix can become singular and it is thus to better use the elastic matrix to converge.

◊   MATRIX   =   /'ELASTIC'

The matrix used corresponds to the elastic design: it is evaluated only once at the initial moment, at the beginning of algorithm. This "elastic" matrix is calculated by using the Young modulus given under the keyword `ELAS` of the operator `DEFI_MATERIAU`, and not the slope at the origin of the traction diagram given under the keyword `TRACTION` (and which is useful, it, in the expression of the relations of behavior `VMIS_ISOT_TRAC`, `VMIS_ECMI_TRAC`, `VISC_ISOT_TRAC` [U4.51.11]).

3.12.3 Operand EVOL_NOLI

◊   EVOL_NOLI = evol_noli

Name of the concept of the type `evol_noli` who will be useful in the prediction by `DEPL_CALCULE`.

3.12.4 Operand MATR_RIGI_SYME

◊   MATR_RIGI_SYME   =   /'NOT'   [DEFECT]
                      =   /'YES'

This operand is used to force the symmetry of the matrix of rigidity. It is useful when one uses **at the same time** a functionality using a not-symmetrical matrix (formalism of Simo-Miehe, loadings of type following pressure, etc) and the formulation of contact of the type `DISCRETE` or `LIAISON_UNIL` (*cf.* [U4.44.11]). Indeed, these last can function only with one matrix of symmetrical rigidity. The fact of making the matrix of rigidity symmetrical has effects on the speed of convergence, being able to go until its failure but will never produce false results. If the fact of symmetrizing the matrix of rigidity makes impossible the convergence of the algorithm of Newton, the user is invited to use a formulation of contact of the type `CONTINUOUS`, which functions with a not-symmetrical matrix of rigidity.

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3.13 Keyword MODELE_REDUIT

Specify the characteristics of the method of resolution of the non-linear incremental problem by a method of reduction of model (see [R5.01.05]).

```
◊    PREDICTION   =   /'TANGENT'
                      /'ELASTIC'
                      /'EXTRAPOLATE'
                      /'DEPL_CALCULE'
◊    MATRIX       =   /'TANGENT'
                      /'ELASTIC'
◊    REAC_INCR        =   /1                    [DEFECT]
                          /mf
◊    REAC_ITER        =   /1                    [DEFECT]
                          /it
◊     EVOL_NOLI        = evol_noli
♦    BASE_PRIMAL    =   mode_empi
◊    DOMAINE_REDUIT  =   /'NOT'                 [DEFECT]
                         /'YES'
   If DOMAINE_REDUIT = 'YES'
         ♦   GROUP_NO_INTERF = grno
         ◊    CORR_COMPLET         = /'NOT'      [DEFECT]
                                     /'YES'
         If CORR_COMPLET = 'YES'
            ♦   GROUP_NO_ENCASTRE   = grno
            ◊   COEF_PENA            = /1.0E 6 ,      [DEFECT]
                                      /coef_pena [R]
```

Keywords MATRIX, PREDICTION, REAC_ITER, REAC_INCR and EVOL_NOLI the same significance and the same use as in the keyword factor have NEWTON (see §3.12).

It is necessary to provide an empirical base built on displacements (thanks to the operator DEFI_BASE_REDUITE). This base must be built on the same model and the same grid as calculation STAT_NON_LINE.

The reduction of model is not compatible with the following features:
  • With contact and friction,
  • With piloting,
  • With linear research,
  • With Lbe dualized limiting conditions (AFFE_CHAR_MECA): it is necessary to use AFFE_CHAR_CINE,
  • With Lbe model mixed: the reduction of model is only compatible with finite elements in displacement.

It is possible to activate the very-reduction which uses a method of the type DEIM (discrete Empirical Method Interpolation). In this case, calculation is tiny room on a zone of the grid restricted (called RID) and built using the operator DEFI_DOMAINE_REDUIT. It is necessary to give the group of nodes on which the interface using the keyword is defined GROUP_NO_INTERF.

To improve quality of the results in very-reduction (DOMAINE_REDUIT=' OUI'), it is possible to make a correction of calculation very-tiny room by a calculation finite element detailed with CORR_COMPLET=' OUI'. For that, it is necessary to define a group of nodes being used to make the connection between the RID and the rest of the model with the keyword GROUP_NO_ENCASTRE (definite for example in the order DEFI_DOMAINE_REDUIT). This group of nodes makes it possible to impose the limiting conditions of Dirichlet necessary so that the problem **corrected** that is to say well defined. These limiting conditions being defined by penalization, the coefficient of penalization can be changed by the keyword COEF_PENA.

Note: this correction always being done on the reduced field, it will not be as precise as a true detailed calculation (complete field). Nevertheless, it is very useful when one significantly changes the limiting

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conditions between the definition of the reduced base (off-line phase in `DEFI_BASE_REDUITE`) and calculation using this reduced base (online phase in `STAT_NON_LINE`).

3.14 Keyword RECH_LINEAIRE

◊ RECH_LINEAIRE=_F ()

Linear research can make it possible to improve convergence of the method of Newton (cf [R5.03.01] for more details).

Caution:
It is disadvised using linear research with the deformations `GROT_GDEP` for modelings `COQUE_3D` and in the presence of contact.

3.14.1 Operand METHOD

◊ METHOD = /'CORD' [DEFECT]
/'MIXED'
/'PILOTING'

Allows to choose the linear research method, i.e. the algorithm of research of the zero of the functional calculus (see Doc. [R5.03.01]). Method `CORD` (by default) is the simplest method, it is a unidimensional secant method.

Method `MIXED` is worked out and uses a secant method with variable terminals. It is more effective when the functional calculus is not strictly concave (problems with damage or THM for example).

Method `PILOTING` is reserved for the piloting of the type `DEFORMATION`, `PRED_ELAS` and `LONG_ARC` (see §27). It is the only method usable with this kind of piloting. For the piloting of the type `DDL_IMPO`, one can use `CORD` or `MIXED`.

3.14.2 Operand RESI_LINE_RELA/ITER_LINE_MAXI

◊ RESI_LINE_RELA = /1.E-1 [DEFECT]
/reslin
◊ ITER_LINE_MAXI = /3 [DEFECT]
/itelin

They are the parameters of linear research. The maximum iteration count is given `itelin` to carry out and precision `reslin` to reach to carry out the convergence of linear research. It is advised not to use linear research with contact.

For the method `CORD`, It is not necessary to specify a precision nor an iteration count very high, the practice showing that two or three iterations of linear research are sufficient. One can thus be satisfied to ask for three iterations with the precision by default. The user cannot put more than 999 iterations of linear research for the method `CORD`.
On the other hand, for the method `MIXED`, on problems with damage, several tens of iterations are often effective.

3.14.3 Operands RHO_MIN/RHO_MAX/RHO_EXCL

◊ RHO_MIN = / 1.E-2 [DEFECT]
/ rmin [R]
◊ RHO_MAX = / 1.E+1 [DEFECT]
/ rmax [R]
◊ RHO_EXCL = / 9.E-3 [DEFECT]
/ rexc [R]

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These keywords fix the interval I in which one calculates the coefficient RHO linear research, in the form: $I = [rmin, rmax] - [-rexc, rexc]$ [R5.03.01].

3.15 Keyword **PILOTING**

◊   PILOTING = _F ()

When intensity η of part of the loading is not known a priori (loading known as of reference defined in AFFE_CHAR_MECA or AFFE_CHAR_MECA_F with load of the type FIXE_PILO), the keyword PILOTING allows to control this loading via a node (or node groups) on which one can impto dare various modes of piloting (keyword TYPE).

Caution:

•*With FIXE_PILO , one cannot use for the loading of reference the keyword FONC_MULT .*
•*When the loading of reference is defined by AFFE_CHAR_MECA_F , this loading can be a function of the variables of space but not of time. In the same way, changes resulting from variables of order (as the temperature) which depend on time are not usable with piloting.*
• *The keyword PILOTING is interdict with the contact (except in the case of the contact XFEM).*
•*It is not possible to make PILOTING with PREDICTION=' DEPL_CALCULE' or PREDICTION=' EXTRAPOLE' (see § 22)*

3.15.1 Operand **TYPE**

◊   TYPE = /'DDL_IMPO'
               /'LONG_ARC '
               /'ANA_LIM'
               /'DEFORMATION
               /'PRED_ELAS'
               /'SAUT_IMPO'
               /'SAUT_LONG_ARC'

It is the type of piloting carried out. Seven modes of piloting are available (Confer [R5.03.80] for more details):

/'DDL_IMPO'

Allows to impose a given value of increment of displacement (only one component i possible) in a single node No (or of a group of nodes comprising one node). With each increment of time, one seeks the amplitude η loading of reference which will make it possible to satisfy the following incremental relation:

$$\text{cmult} . \Delta u_i(no) = \Delta t$$

/'SAUT_IMPO'

The principle begins again of DDL_IMPO but to control the increment of the jump of displacement enters the lips of a crack X-FEM. Only one direction i is possible, but it can be defined in a local base (normal or tangent with the crack). One controls the average of this increment of jump on a set of points of intersection P_a interface with the edges a grid. This unit describes all the crack if GROUP_NO is not well informed (behavior by default), and only one part if it is it. Attention, this kind of piloting can be used only in modeling X-FEM.

$$\text{cmult} . \frac{1}{N} \sum_{a=1}^{N} [\![\Delta u_i]\!](P_a) = \Delta t$$

/'LONG_ARC'

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Allows to control the intensity η loading of reference by the length (curvilinear X-coordinate) of the answer in displacement of a group of nodes (to be used for example when one wants to control the buckling of a test-tube). The following relation is checked:

$$\text{cmult}.\|\Delta u\| = \Delta t \text{ with } \|(\Delta u)\| = \left(\sqrt{\sum_n \sum_c (\Delta u_{n,c}^2)}\right)$$

where *N* are the nodes of piloting and *C* components of the displacement of the nodes considered. Even if the group of node of piloting is tiny room to only one node, it is necessary nevertheless to use GROUP_NO.

/ 'SAUT_LONG_ARC'

The principle begins again of LONG_ARC but to control the standard of the increment of the jump of displacement enters the lips of a crack X-FEM. One controls this standard on average on a set of points of intersection P_a interface with the edges a grid. This unit describes all the crack if GROUP_NO is not well informed (behavior by default), and only one part if it is it.

$$\text{cmult}.\|[\![\overline{\Delta u}]\!]\| = \Delta t \text{ with } \|[\![\overline{\Delta u}]\!]\| = \sqrt{\frac{1}{N} \sum_c \sum_{a=1}^{N} ([\![\Delta u_c]\!](P_a))^2}$$

where C are the components of displacement. Even if the group of node of piloting is tiny room to only one node, it is necessary nevertheless to use GROUP_NO.

/ 'ANA_LIM'

This mode of piloting is specific to the calculation of load limits (law NORTON_HOFF) by kinematic approach (cf [R7.07.01] for more detail). If $\mathbf{F}$ indicate the controlled assembled loading, TYPE_CHARGE=' FIXE_PILO', then the function of piloting is written simply:

$$P(\mathbf{u}) = \mathbf{F}.\mathbf{u} = 1$$

Except for the calculation of limiting load, this functionality is not of interest *a priori*. For this mode of piloting, no other keyword is to be specified.

The use of lenitive laws of behavior can lead to brutal snap-backs which make delicate the course of calculation. The two following modes of piloting cure it (cf [R5.03.80] for more detail).

/ 'DEFORMATION'

DEFORMATION guarantees that at least a point of Gauss of the structure sees its deformation evolving in a monotonous way. The relation is checked:

$$\text{cmult}.max_{\text{point de Gauss}}\left(\frac{\dot{\varepsilon}}{\|\dot{\varepsilon}\|}.\Delta\varepsilon\right) = \Delta t$$

This mode of piloting is valid for all the laws of behavior including in great deformations SIMO_MIEHE.

/ 'PRED_ELAS'

PRED_ELAS ensure that at least a point of Gauss of the structure left the threshold of elasticity linearized $f_{\text{pred-elas}}$ of a quantity $\dfrac{\Delta t}{\text{cmult}}$. The relation is checked:

$$\text{cmult}.\max_{\text{point de Gauss}}(f_{\text{pred-elas}}) = \Delta t$$

This mode of controlledGe is valid only for the laws ENDO_SCALAIRE (with nonlocal version), ENDO_FISS_EXP (nonlocal only), ENDO_ISOT_BETON and ENDO_ORTH_BETON (with the local version and the nonlocal version), BARENBLATT, BETON_DOUBLE_DP, CZM_EXP (with the

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elements with internal discontinuity *_ELDI) , CZM_OUV_MIX and CZM_TAC_MIX (elements of interface *_INTERFACE), CZM_EXP_REG (elements of joint *_JOINT or modeling X-FEM) and CZM_LIN_REG (elements of joint).

The fixing of the parameter cmult is difficult to define first blow because the concept of exit of criterion $\frac{\Delta t}{\text{cmult}}$ is not intuitive and varies according to the laws of behavior. For the laws ENDO_SCALAIRE, ENDO_FISS_EXP and ENDO_ISOT_BETON, a version different from the definition from $\frac{\Delta t}{\text{cmult}}$ is used, where this parameter is related to the increment of damage (see [R7.01.04]).

Use – Attention:

When one wants to use these the last two modes of piloting, it is essential to make a first STAT_NON_LINE without the keyword PILOTING to start the problem and to obtain an initial state ε^- different from zero (if not divide check for piloting by increment of deformation). One carries out after a recovery starting from this initial state not no one and one uses piloting.

Moreover, the resolution of the two preceding equations makes it possible to obtain the unknown intensity of the loading. In certain cases, the solution of these equations can lead to several solutions for the intensity. One then chooses always the solution which is closest to ε^-. This is why, when one wants to impose an alternated loading, one is obliged with each change of sign of the loading to carry out a first STAT_NON_LINE without the keyword PILOTING in order to obtain an initial state ε^- of traction or compression. One carries out then a second STAT_NON_LINE in continuation starting from the preceding initial state with the keyword PILOTING.

Note:

    | *DEFORMATION and PRED_ELAS are not available for the elements of structures.*

3.15.2 Operands NOEUD/GROUP_NO

```
/ NODE      =   No
/ GROUP_NO  =   grno
```

To use only with 'DDL_IMPO', 'LONG_ARC', 'SAUT_IMPO' or 'SAUT_LONG_ARC'. For 'DDL_IMPO', if the operand is used GROUP_NO, the group of nodes in question should contain one node. In the other cases, one only uses GROUP_NO (which can possibly contain one node). For 'SAUT_IMPO' and 'SAUT_LONG_ARC', the operand is optional.

For 'DDL_IMPO' and 'LONG_ARC', ON gives the name of the node or the name of the group of nodes on which one will impose piloting.

For 'SAUT_IMPO' and 'SAUT_LONG_ARC', the definition is more subtle since in modeling X-FEM one does not control the values on nodes but on points of intersection between edges of the grid and the crack. In the continuation, one simply indicates by "edges" the intersected edges. The algorithm starts with to build a set of independent edges which covers all the crack (see fig.3.15.2-1). By default, it controls on all these edges. The keyword GROUP_NO allows the user to restrict this unit, each node well informed corresponding then at the end of an edge which one wishes to control. Let us announce the following rules then:
•   if two nodes are the respective ends of two nonindependent edges, only one will be retained (fig. 3.15.2-2),
•   if a node is end of several edges, one arbitrarily retains the first met by the algorithm,
•   if two nodes are ends of the same crack (fig.3.15.2-3) an error will be returned. Generally it is advised that all the entered nodes are same side of the crack;
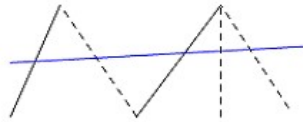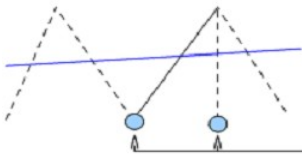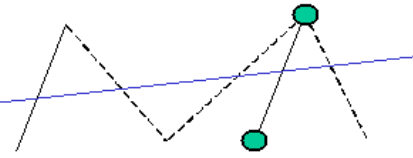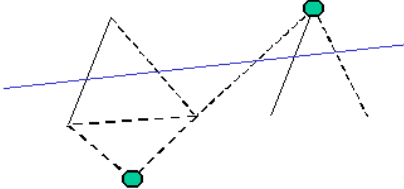•   if a node does not correspond to any edge (fig. 3.15.2-4), an error is returned.

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Figure 3.15.2-1: `GROUP_NO`
nonwell informed

Figure 3.15.2-2: Nodes ends of
nonindependent edges

Figure 3.15.2-3: error for nodes
connected to the same edge

Figure 3.15.2-4: error for node
off-line to an intersected edge

Table 3.1.

3.15.3 Operands ALL/MESH/GROUP_MA

```
/ ALL      =  'YES'           [DEFECT]
/ GROUP_MA  =  lgrma
/ MESH    =  lma
```

One gives the meshs or groups of meshs being used to control calculation. With to use only with DEFORMATION or PRED_ELAS. Interesting to reduce the resolution of the equations of these three modes of pilotings.

3.15.4 Operand DIRE_PILO

◊   DIRE_PILO = direpilo

It is the name of the direction i according to which one controls the jump of displacement. The possible values are: 'DX','DY','DZ','DNOR'for the normal with the crack,'DTAN'for the first tangent (product vector of the normal with X), 'DTAN2'for the second tangent. To use only with one modeling X-FEM. Use for the types 'SAUT_IMPO', 'SAUT_LONG_ARC' or with 'PRED_ELAS' if the selection on the choice of the controlled solution is 'ANGL_INCR_DEPL' or 'NORM_INCR_DEPL'.

3.15.5 Operand CRACK

◊   CRACK = fiss

Name of sd_fiss_xfem. To use only with one modeling X-FEM. Use for the types 'SAUT_IMPO', 'SAUT_LONG_ARC' or with 'PRED_ELAS' if the selection on the choice of the controlled solution is 'ANGL_INCR_DEPL' or 'NORM_INCR_DEPL'.

3.15.6 Operand NOM_CMP

◊   NOM_CMP = nomcmp

It is the name of the component (corresponding to the degree of freedom i) used for piloting ('DX' for example). To use only with 'DDL_IMPO' or 'LONG_ARC'.

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3.15.7 Operand COEF_MULT

◊   COEF_MULT = cmult

It is the value (noted in the formula of definition) by which one multiplies the degree of freedom used for piloting. By default, this value is worth 1. With not to use with ANA_LIM.

Example with DDL_IMPO:

Let us suppose that one wants to know the limiting load of a structure.

The loading imposed on the structure is the pressure of unknown intensity ($P = \eta \times$ valeur de référence P_x) on the group of mesh A. To find the limiting load P_{limite}, one will control the displacement of the node $NO1$. It is wanted that following final displacement x this node is equal to $2.$ (either according to the list of moments of the steps of 0.2, that is to say a coefficient $cmult = 1/0.2 = 5.$)

```
PRESSURE  = AFFE_CHAR_MECA (NEAR        = (GROUP_MA =A,   PX = 1.0)),

LIST      = DEFI_LIST_REEL (BEGINNING       =0. ,
                           INTERVAL =_F (UNTIL = 10,  NUMBER =10),

RESU      = STAT_NON_LINE (EXCIT        =_F ( LOAD       = PRESSURE,
                                             TYPE_CHARGE = '
FIXE_PILO'),
                          PILOTING     =_F ( TYPE        =
'DDL_IMPO',
                                            NODE        = NO1,
                                            NOM_CMP     = 'DX',
                                            COEF_MULT   = 5.))
```

In the file .resu, the value of η calculation will be displayed at every moment. To know the limiting load, it is enough to make $P_{limite} = \eta \times P_x$. (Here P_x 1 thus one is worth has the limiting load directly). If one imposes on the structure a pressure P near to the limiting load without using piloting, calculation will not converge if one is close to the limiting load.

Attention with the significance of COEF_MULT for the piloting of the type PRED_ELAS.

3.15.8 Operand ETA_PILO_R_MAX/ETA_PILO_R_MIN

◊   ETA_PILO_R_MAX = etarmax,   [R]
◊   ETA_PILO_R_MIN = etarmin,   [R]

These two keywords make it possible to define the interval of research of the values of piloting. With each iteration of Newton all values of piloting apart from $[etarmin, etarmax]$ are ignored. This can take along to "failure of piloting" if this interval is too restrictive.

If one does not specify values, it is $-\infty$ for etarmin and $+\infty$ for etarmax. A possible use of this interval is the following. One wishes, for example, to control a pressure imposed on the structure and one expects to keep this positive pressure. While fixing etarmin to 0, that makes it possible to impose the positive values of piloting.

3.15.9 Operand ETA_PILO_MAX/ETA_PILO_MIN

◊   ETA_PILO_MAX   = etamax,   [R]
◊   ETA_PILO_MIN   = etamin ,   [R]

These two keywords make it possible to specify the interval of values of desired piloting. Is used it to stop calculation properly when ETA_PILOTAGE reached the terminals of this interval. This interval must be more restrictive than the interval of research defined previously, because this last is

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applied in all the cases. The principle of operation is the following: with convergence of the iterations of Newton, if one reached one of the terminals, calculation stops. A possible use of this interval is the following one. In the case of presence of snap-back while fixing *etamin* with a low value, that makes it possible to stop calculation before a tear/complete damage of the sample and to thus avoid the divergence with the last step of time. The other possible use is that of *etamax* as a maximum limiting load.

Caution:

With the law ENDO_ISOT_BETON *, these two keywords are obligatory, because they are used to fix the terminals of piloting at the elementary level.*

3.15.10 Operand PROJ_BORNES

◊   PROJ_BORNES = /'YES'   [DEFECT]
                 /'NOT'

In the event of going beyond the interval (etamin, etamax), the user can indicate if he wants to project the value of piloting on (etamin, etamax).
With PROJ_BORNE=' OUI', projection will be carried out (if eta>etamax then eta=etamax ; if eta<etamin then eta=etamin), which allows, in the event of convergence to precisely stop calculation on etamin or etamax.
With PROJ_BORNE=' NON', one does not modify the values of eta, even if during the iterations of Newton the latter has a value higher than etamax or lower than etamin. On the other hand calculation is stopped, so with convergence eta the terminals exceed.

A possible use of the interval (etamin, etamax) with the option PROJ_BORNE=' OUI' is the following. One wishes, for example, to compare several calculation for a lenitive model, which is to control in displacement. These parameters of piloting make it possible to stop calculations with the same loading when the structure is sufficiently softened. This strategy makes easier the comparison, thanks to the control of the last point of piloting.

With PROJ_BORNE=' NON' one manages in certain cases to resolve calculations, which differently do not converge with the too restrictive conditions imposed via (etarmin, etarmax). Either one controls a pressure imposed on the structure and one expects to keep this positive pressure. While fixing etarmin to 0 calculation stops in failure of piloting. On the other hand while imposing etarmin slightly negative, one de facto authorizes the passage by a state "not physics" during the iterations of Newton, which facilitates convergence. The state converged in this case can as well be physical (positive pressure) or not physical. It is the value of etarmin=0, who will control the behavior in the event of convergence except terminal. This strategy makes it possible to preserve only the positive values of piloting, if one finds at least a value of piloting positive.

3.15.11 Operand SELECTION

◊   /SELECTION = /'NORM_INCR_DEPL',   [DEFECT]
                /'ANGL_INCR_DEPL',
                /'RESIDUE'
                /'MIXED'

This operand makes it possible to select the method allowing for choice of the value of piloting if several solutions are provided by the resolution of piloting.
'NORM_INCR_DEPL' allows to select the value of piloting by the smallest standard of the increment of displacement on the step of time considered.
'ANGL_INCR_DEPL' allows to select the value of piloting by the smallest angle between the displacement obtained for the step of current time and the displacement obtained for the step of previous time.
'RESIDUE' allows to select the value of piloting leading to the smallest residue.

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'MIXED' allows to select the value of piloting while being based on several strategies. One starts initially with the strategy 'NORM_INCR_DEPL' above. If the results of the function objective (the standard of the increment of displacement) are too close, one rocks for this iteration on the strategy 'RESIDU'. There still, if the residues are too close, one returns to the strategy 'NORM_INCR_DEPL' and one examines whether the list of the residues 'RESI_GLOB_MAXI' step of current time presents cycles. If it is the case, it is less the good solution of 'NORM_INCR_DEPL' who is selected for this iteration. If not, one chooses simply the best of both, even if they are not sufficiently contrasted.

Note:

If one makes a resumption of calculation (reuse) with the keyword SELECTION=' ANGL_INCR_DEPL', it is important to keep in mind that this criterion requires them two pas de previous times. It will thus be necessary well to take care to correctly file the results of the preceding calculation to the risk getting false results. An alarm informs the user.

3.15.12 Operand EVOL_PARA

◊   EVOL_PARA   = /'WITHOUT'   [DEFECT]
                                    /'DECREASING'
                                    /' GROWING '

This operand makes it possible to impose it to it growth or the decrease of the parameter of piloting.

3.16 Keyword SOLVEUR

◊   SOLVEUR =_F ()

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

3.17 Keyword CONVERGENCE

◊   CONVERGENCE =_F ()

If none of the two operands following is present, then all occurs like if: RESI_GLOB_RELA = 1.E-6.

3.17.1 Operand RESI_GLOB_RELA/RESI_GLOB_MAXI

◊ |RESI_GLOB_RELA = resrel ,   [R]

The algorithm continues the total iterations as long as:

$$\underset{i=1,\ldots,nbddl}{max} |F_i^n| > \text{resrel} . max|\boldsymbol{L}|$$

where $\boldsymbol{F}^n$ is the residue of the iteration n and $\boldsymbol{L}$ the vector of the imposed loading and the reactions of supports (cf [R5.03.01] for more details).

When the loading and the reactions of support become worthless, i.e. when $\boldsymbol{L}$ is null (for example in the case of a total discharge), one tries to pass from the relative convergence criteria RESI_GLOB_RELA with the absolute convergence criteria RESI_GLOB_MAXI. This operation is transparent for the user (message of alarm emitted in the file .mess). When the vector $\boldsymbol{L}$ becomes again different from zero, one passes by again automatically with the relative convergence criteria RESI_GLOB_RELA.

However, this mechanism of swing cannot function with the first step of time. Indeed, to find a value of RESI_GLOB_MAXI reasonable in an automatic way (since the user did not inform it), one needs to have had at least a step converged on a mode RESI_GLOB_RELA . Consequently, if the loading is null as of the first moment, calculation stops. The user must already then check that the null

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loading is normal from the point of view of the modeling which it carries out, and if such is the case, to find another convergence criteria (RESI_GLOB_MAXI for example).

If this operand is absent, the test is carried out with the value by default, except if RESI_GLOB_MAXI is present.

◊ |RESI_GLOB_MAXI =   resmax ,   [R]

The algorithm continues the total iterations as long as:

$$\underset{i=1,\dots,nbddl}{max} |\boldsymbol{F}_i^n| > \text{resmax}$$

where $\boldsymbol{F}^n$ is the residue of the iteration n (Cf [R5.03.01] for more details). If this operand is absent, the test is not carried out.

If RESI_GLOB_RELA and RESI_GLOB_MAXI both are present, the two tests are carried out.

Note:

If the limiting conditions of Dirichlet are imposed by AFFE_CHAR_CINE (elimination) and not by AFFE_CHAR_MECA (dualisation), the degrees of freedom carrying these conditions are ignored during the evaluation of the residue of balance. What does not cause false results but when the loading becomes null, i.e. when $\boldsymbol{L}$ is null (for example in the case of a total discharge), one passes from the convergence criteria relating to the absolute convergence criteria RESI_GLOB_MAXI. This operation is transparent for the user (message of alarm emitted in the file .mess). When the vector $\boldsymbol{L}$ becomes again different from zero, one passes by again automatically with the relative convergence criteria RESI_GLOB_RELA.

3.17.2 Operand RESI_COMP_RELA

◊ |RESI_COMP_RELA =   rescmp ,   [R]

This operand results in considering the convergence of the algorithm of Newton while reasoning component by component. For that, one distinguishes in the vector residue the under-vectors corresponding to each component cmp (for example in THM, $cmp = [DX, DY, DZ, PRE1, PRE2, TEMP]$). One normalizes then these under-vectors by the corresponding internal force. Thus, the algorithm continues the total iterations as long as:

$$\underset{c=1,\dots,nbcmp}{max} \left(\frac{\underset{i=1,\dots,nbddl}{max} |\boldsymbol{F}_i^{c,n}|}{\underset{i=1,\dots,nbddl}{max} |\boldsymbol{L}_i^{\text{int},c,n}|} \right) > \text{rescmp}$$

where $\boldsymbol{F}^{c,n}$ is the part of the residue $\boldsymbol{F}^n$ corresponding to the component c and $\boldsymbol{L}^{\text{int},c,n}$ the vector of the internal forces at time n correspondent with this same component c (Cf [R5.03.01] for more details).

Internal forces at time n are calculated at the beginning of step of time starting from the result resulting from the step of previous time. For the first step of time, one passes automatically to a relative criterion of type RESI_GLOB_RELA, to see with an absolute criterion for the cases where the loading is null. This choice is interested only in problems of the evolutionary type (THM) where resident of strong contrasts between the various unknown factors.

3.17.3 Operand RESI_REFE_RELA

| RESI_REFE_RELA   =   resref,   [R]
     SIGM_REFE   =   sigref,   [R]

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```
    EFFORT_REFE         =   forref,        [R]
    MOMENT_REFE         =   momref,        [R]
    VARI_REFE           =   varref,        [R]
    EPSI_REFE           =   epsref,        [R]
    FLUX_THER_REFE      =   fthref,        [R]
    FLUX_HYD1_REFE      =   fh1ref,        [R]
    FLUX_HYD2_REFE      =   fh2ref,        [R]
    DEPL_REFE           =   depref,        [R]
    LAGR_REFE           =   lagref,        [R]
```

This operand results in estimating the convergence of the algorithm of Newton in the following way. From a reference, which can be:

*   A constraint `sigref` ;
*   A deformation `epsref` for incompressible elements, elements of grid and membrane;
*   An internal variable `varref` if one uses nonlocal laws with gradient of deformation;
*   A heat flux `fthref` in a case THM;
*   Two hydrous flows `fh1ref` and `fh2ref` in a case HHM;
*   A displacement `depref` if one uses elements of joint with a behavior of the type CZM;
*   A force `forref` and a moment `momref` if elements of structure are used (discrete, bars, beams or cables);
*   A coefficient of Lagrange `lagref` for the mixed formulations in damage.

A reference of residue is calculated F^{ref} (of a the same vector length than the vector residue). Convergence will be carried out if and only if:

$$\forall\, i \in [1, \dots, nbddl] \quad |F_i^n| < \mathrm{resref} \,.\, F_i^{ref}$$

3.17.4 Operand **ITER_GLOB_MAXI**

◊   ITER_GLOB_MAXI =   /10   [DEFECT]
                        /maglob

Maximum iteration count carried out to solve the total problem at every moment (10 by defaults). This test is always carried out except in the case of the recutting of the step of time by method 'EXTRAPOLATES'. The excessive increase in this parameter is generally the sign of a problem in modeling or an inadequate temporal discretization.
In the case of the resolution of a problem of contact/friction by the formulation CONTINUOUS in generalized Newton, it is often necessary to increase the iteration count of Newton.

3.17.5 Operand **ITER_GLOB_ELAS**

◊   ITER_GLOB_ELAS =   /25   [DEFECT]
                        /maxelas

Maximum iteration count carried out with the elastic matrix when the keyword is used PAS_MINI_ELAS keyword factor NEWTON (see §22) to solve the total problem at every moment (25 by defaults).

It is pointed out that PAS_MINI_ELAS allows to pass from the tangent matrix to the elastic matrix when the step of time is or becomes (by recutting) lower than a certain value specified under PAS_MINI_ELAS.

Contrary to ITER_GLOB_MAXI, this parameter can easily take great values (several hundreds) because convergence on a non-linear problem with the elastic matrix (very stiff) slow although is ensured from the theoretical point of view for all the laws describing generalized standard materials.

3.17.6 Operand **STOP**

◊   STOP =/'YES'   [DEFECT]

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If one of the selected convergence criteria total is not checked afterwards `maglob` iterations, then the program stops (the preceding results are saved).

◊   STOP =/'NOT'   [DEFECT]

If `maglob` is insufficient to check the convergence criteria given by the user, one passes nevertheless at the next moment. This option is usable only in mode `DEPL_CALCULE`.
This option is to be used with precaution because it gives false results.

3.18 Keyword CRIT_STAB

◊   CRIT_STAB =_F ()

This keyword makes it possible to start calculation, at the end of each increment of time, of a criterion of stability. This criterion is useful to detect, during the loading, the point from which one loses stability.

•   By buckling in the case of mechanical phenomenon reversible (TYPE = 'BUCKLING') :

This criterion is then calculated in the following way: at the end of a step of time, in small disturbances, one solves $det\left(K^T + \mu \cdot K^g\right) = 0$. K^T is the coherent tangent matrix at this moment.

K^g is the geometrical matrix of rigidity, calculated starting from the stress field at this moment.

In practice, the loading is unstable if the critical load factor μ check $|\mu| < 1$ (in fact $0 < \mu < 1$). One calculates the eigenvalues by the method of Sorensen (*cf.* CALC_MODES [U4.52.02]). This can be expensive enough for the problems of big size. For great displacements and the great deformations, one solves $det\left(K^T + \mu \cdot I\right) = 0$ because K^T contains then K^g. The criterion is then a criterion of instability: when μ change sign (thus passes by 0) the loading is unstable. One stores the clean mode the corresponding to smallest critical load (in absolute value) in the result object, under the name MODE_FLAMB . This clean mode can be extracted and visualized (like a field of displacements or a classical clean mode). It is standardized to 1 on the largest component of displacement. The linear analysis of stability not making it possible to take account of the following aspect of certain forces, it is then necessary to use CRIT_STAB.
Documentation [U2.08.04] present the various approaches for the analyses of buckling in Code_Aster.

•   By a study of sign on the derivative second of energy by respecting the increase in the irreversible degrees of freedom in the case of a dissipative mechanics (TYPE = 'STABILITY') :

To treat this typical case, one forces to take as stamps geometrical rigidity the matrix identity $K^g = I_d$. One searches then the minimum of following quadratic functional calculus:

$$C(x) = \frac{x^t \cdot K^T x}{x^t \cdot x}$$ where K^T is the coherent tangent matrix at the studied moment and x^t the

vector transposed of the field of unknown nodal x , under constraints of positivity on the degrees of freedom of x of irreversible nature. The sign of the minimum then makes it possible to conclude on the stability of the loading. If this one is negative, the solution is unstable. In the contrary case, the solution obtained numerically is stable. The mode obtained, which is the minimizing vector $C(x)$ (known as mode of instability if the minimum is negative), and the estimate of the associated criterion of stability are stored in the result object under the name MODE_STAB (CHAR_STAB = $C(x)$).

The whole of the results is stored in a structure of data of the type table_container of name 'ANALYSE_MODALE' attached to the structure of data evol_noli . Modes of buckling (TYPE='

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FLAMBEMENT') are stored like TYPE_MODE=' MODE_FLAMB ' in the table while modes of stability (
TYPE=' STABILITY ') there are stored like TYPE_MODE=' MODE_STAB ' (see [U4.53.01]).

3.18.1 Operand LIST_INST / INST / PAS_CALC

◊   /'LISTE_INST' = list_r8
    /'INST'   = l_r8
    /'PAS_CALC'   = npas

The moments for which one wants to do a calculation of stability are given by a list of moments
(list_r8 or l_r8) or by a frequency PAS_CALC (all them *npas* time).
In the absence of these keywords the criterion is calculated with all the steps of time.

3.18.2 Operand PRECISION/CRITERE

◊   PRECISION   = /1.e-6   [DEFECT]
                   /prec
◊   CRITERION   = /'RELATIVE',   [DEFECT]
                    /'ABSOLUTE',
 Allows to select the moments, *confer* [U4.71.00]

3.18.3 OperandS OPTION/CHAR_CRIT/ NMAX_CRIT

◊   OPTION   = /' PLUS_PETITE ',   [DEFECT]
                /'BAND',
                /'CALIBRATION',
 If OPTION=' PLUS_PETITE'
 {
   ◊   NMAX_CRIT   = /3,   [DEFECT]
                          /nbfreq,   [I]
 }
 If OPTION=' BANDE'
 {
   ◊   CHAR_CRIT   = intba ,   [listr8]
 }
 If OPTION=' CALIBRATION'
 {
   ◊   CHAR_CRIT   = intba ,   [listr8]
}

The keyword OPTION allows to choose the type of research:
   • OPTION=' PLUS_PETITE' : NMAX_CRIT clean vectors and eigenvalues corresponding to
     the smallest eigenvalues;
   • OPTION=' BANDE' : clean vectors and eigenvalues for critical loadings understood in the
     band CHAR_CRIT;
   • OPTION=' CALIBRATION' of which just the number of eigenvalues for loadings criticisms
     understood in the band CHAR_CRIT ; .

3.18.4 Operand COEF_DIM_ESPACE

◊   COEF_DIM_ESPACE = / 5,   [DEFECT]
                       / coeff

The keyword COEF_DIM_ESPACE (5 is its value by default) allows the user to control the size of the
subspace in the method of Sorensen (the size of under space is equal to the multiplication of this
coefficient by the value nbfreq informed previously). Interest being to be able to reduce this space
if one uses in more the operand DDL_STAB.

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3.18.5 Operand RIGI_GEOM

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

The keyword RIGI_GEOM ('YES' by default) gives the choice to the user between or not carrying out a search for eigenvalues generalized with the geometrical matrix with the second member (case of the great deformations). To choose 'NOT' mean that the geometrical matrix of stiffness is replaced by the identity.

3.18.6 Operand MODI_RIGI

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

The keyword MODI_RIGI ('NOT' by default) makes it possible to specify if the matrix of total rigidity (and stamps it geometrical rigidity if it is used) must be modified on the level of the degrees of freedom which one lists with DDL_EXCLUS. That allows, for example, for mixed models, not to carry out the analysis of stability by excluding certain type of degree of freedom and by correcting the total matrices of rigidity so that the terms related to these degrees of freedom do not come to disturb the search for instability. One gives other details in the paragraph devoted to DDL_EXCLUS. If the list of excluded degrees of freedom is empty, then MODI_RIGI is not thus used for nothing.

3.18.7 Operand DDL_EXCLUS

◊   DDL_EXCLUS = ('DX', 'DY',…)

The keyword DDL_EXCLUS (list empties by default) the whole of the degrees of freedom indicates which one wishes to put at 0 in the second member of the search for generalized eigenvalues. It can be used only under the condition RIGI_GEOM = 'NOT' or if MODI_RIGI = 'YES'.

In the case RIGI_GEOM = 'NOT' and MODI_RIGI = 'NOT', Cela makes it possible to impose additional conditions of compatibility on the clean modes and thus to carry out a selective research. That is particularly adapted to the mixed formulations. In this case, the elimination of the multipliers of Lagrange to the second member, makes it possible to exclude the parasitic modes with dominant Lagrangian and of negative eigenvalues.

In the case MODI_RIGI = 'YES' , that makes it possible to modify the matrix of rigidity (and if need be the geometrical matrix of rigidity) so as to carry out the analysis of stability by not taking account of the excluded degrees of freedom. For example, one must use this option for the coupled models fluid-structure (formulation (u, p, ϕ), *confer* documentation [R4.02.02], which is usable with DYNA_NON_LINE but not STAT_NON_LINE) to exclude the degrees of fluid freedom because the matrix from total assembled rigidity is singular for these degrees of freedom. For more details, the user will be able usefully to refer to documentations [U2.06.11] and [U2.08.04].

3.18.8 Operand DDL_STAB

◊   DDL _STAB = ('DAMG',…)

The keyword DDL _STAB indicate the whole of the irreversible degrees of freedom in the study of stability which one wishes to carry out with CRIT_STAB . It can be used only under the conditions: TYPE=' STABILITE' and RIGI_GEOM=' NON' . That makes it possible to carry out a study of sign on the derivative second of energy, with the loading considered, by looking at only the disturbances   likely to increase the degrees of freedom declared in DDL_STAB . This in order to observe the mechanical conditions of irreversibility.

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3.18.9 Operand SIGN

```
◊   SIGN            =  /'POSITIF_NEGATIF',        [DEFECT]
                    =  /'POSITIVE',
                    =  /'NEGATIVE',
```

The keyword SIGN allows to specify which type of criterion of instability will be used. This criterion will make it possible to start a clean stop (bases saved) of non-linear calculation in the event of instability, if the user specifies it, under DEFI_LIST_INST (*confer* documentation [U4.34.03]) with following syntax:

```
ECHEC=_F (EVENEMENT=' INSTABILITE', ACTION=' ARRET',)
```

Without this declaration under DEFI_LIST_INST , even in the event of detected instability non-linear calculation will try to continue: it is the by default mode.

For the analyses of stability without geometrical matrix of rigidity, the criterion of instability is that a critical load tends towards 0, or changes sign. In this case, the keyword SIGN is not useful.

On the other hand, for the cases where the geometrical matrix of rigidity is used, this keyword SIGN is useful. With the value by default: SIGN = ' POSITIF_NEGATIF' , the soluti one will be declared unstable whenever a critical load becomes ranging between -1 and 1. If the user chooses the option 'NEGATIVE' then the field of instability will be limited by values -1 and 0. Conversely, the option 'POSITIVE' will define values 0 and 1 like limits of the field of instability. The by default choice is most conservative, but in certain cases where one can clear part of the field a priori of instability, then it is relevant to modify the criterion with the keyword SIGN . It is pointed out that the critical load calculated by CRIT_STAB , if the geometrical matrix of rigidity is taken into account, is equal with multiplying coefficient of the loading imposed which the problem makes unstable. Thus if the computed value by CRIT_STAB 1 that is worth means that one is unstable for imposed load. If value -1 is obtained, then instability will occur for an imposed load of the same value but of opposite sign. Thus for imposed loadings known and evolving in a monotonous way, it is easy to restrict the field of instability because one knows that the loading cannot change sign. On the other hand, for cyclic or unspecified loadings, it is surer not to restrict the field of instability.

3.18.10 Operand PREC_INSTAB

```
◊  PREC_INSTAB     =  /1.E-6,                     [DEFECT]
                    /prec_instab,                 [R]
```

The keyword PREC_IN STAB allows to define the relative tolerance with which one wishes to check the criterion of instability, which is parameterized by the preceding keyword SIGN .

3.19 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].

3.20 Keyword FILING

```
◊   FILING =_F ()
```

Allows to file or certain results at all or certain moments of calculation.

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In the absence of this keyword all the steps of time are filed, including the moments of calculations lately created by automatic recutting of the step of time. Filing makes it possible to appreciably reduce the size of the bases by selecting the saved moments.

3.20.1 Operand LIST_INST / INST / PAS_ARCH

◊   /'LISTE_INST' = list_r8
   /'INST'   = l_r8
   /'PAS_ARCH'   = npas

The designation of the moments to be stored is carried out either by a list of moments (list_r8 or l_r8) or then by a frequency of filing (all them npas time).
In the absence of these keywords all the steps of time are filed.

> **Remarques:**
>
> 1) LE last step of calculation is always stored to be able to carry out a recovery,
> 2) SI one employs an access by list of moments, then the moments of calculations lately created by automatic recutting of the step of time are not filed
> 3) The initial state is systematically filed under the sequence number 0 since one is not in resumption of calculation (not of *reuse*)
> 4) Fields CONT_NOEU and CONT_ELEM contact are also stored in an initial state but all their components are worthless. In particular, the effect of the keywords CONTACT_INIT and SEUIL_INIT N'is not visible in these fields.

3.20.2 Operand PRECISION/CRITERE

◊   PRECISION   = /1.e-6   [DEFECT]
                  /prec
◊   CRITERION   = /'RELATIVE',   [DEFECT]
                  /'ABSOLUTE',

Cf [U4.71.00]

3.20.3 Operand CHAM_EXCLU

◊   CHAM_EXCLU

Allows to specify the fields which will not be filed, except with the last step of time.
The name of the excluded fields depends on the operators.

3.21 Keyword POSTING

◊   POSTING =_F ()

This keyword factor makes it possible to personalize the posting of the table of convergence in STAT_NON_LINE and DYNA_NON_LINE.

If this keyword is not indicated, the table is built according to the various options of calculation (research linear, piloting, contact, etc) and with INFO_RESIDU=' NON'.

3.21.1 Operand UNIT

◊   UNIT =unit

The table of convergence will be duplicated in the file of unit *links*, with the format .csv (the separator being the comma).

3.21.2 Operand NOT

◊   NOT =pas

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Frequency of reactualization of posting in the file message. This operand makes it possible to reduce the volume of the impressions, particularly in explicit dynamics. He does not affect the reactualization of the file to the format .csv (keyword UNIT).

3.21.3 Operand INFO_RESIDU

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

This operand makes it possible to add a column for each evaluated residue (RESI_GLOB_RELA, RESI_GLOB_MAXI, RESI_COMP_RELA and RESI_REFE_RELA). This column will indicate the node where the residue is maximum, which can help the user when there are difficulties of convergence. For example, to see whether the material were badly defined with an incorrect value on an element.

3.21.4 Operand INFO_TEMPS

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

This operand makes it possible to add a column which to give the time spent in the iteration of Newton.

3.22 Keyword OBSERVATION

◊   OBSERVATION =_F ()
◊   TITLE   = title

This keyword makes it possible post-to treat certain fields with the nodes or the elements on parts of model moments of a list (known as of observation) generally more refined than the list of the moments filed defined in the keyword FILING [§3.20] (where one stores all the fields on all the model). It is used primarily with economies as storage, but also to evaluate fields on reduced parts of the grid, without needing post-to treat after calculation. It is possible, for example, to calculate the standard of the constraints, within the meaning of vone Settings, and to store it in the table of observation.

This keyword is répétable and allows the creation of a table of the same observation name than the concept result of STAT_NON_LINE that one will be able to extract using the order RECU_TABLE. One can use only 99 occurrences of the keyword OBSERVATION to the maximum.
It is possible to name an occurrence of the observation (column NOM_OBSERVATION) by using the keyword TITLE. If it is not used, the column NOM_OBSERVATION contains OBSERVATION_xx with xx varying from 1 to 99.

3.22.1 Operands LIST_INST/INST/PAS_OBSE/OBSE_ETAT_INIT

◊   /'LISTE_INST'   = list_r8
    /'INST'   = l_r8
    /'PAS_OBSE'   = npas
    /'OBSE_ETAT_INIT'   =/'YES',   [DEFECT]
                         /'NOT'

These operands make it possible to define in the choices a list of moments of observation. LIST_INST, INST and PAS_OBSE have the same meaning as of the same operands name being used to define a list of filing. PAS_OBSE playing the same part as PAS_ARCH in FILING [§3.20]. The operand OBSE_ETAT_INIT specify if one must observe the fields at the initial moment because the initial moment is not manageable by the list of moments (keyword LIST_INST, INST).

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3.22.2 Operands PRECISION/CRITERE

```
◊    PRECISION = prec
◊    CRITERION   =/'ABSOLUTE'
                 /'RELATIVE'
```

Cf [U4.71.00] for detailed syntax.
These parameters make it possible to manage the precision of the selection of the moments for the observation.

3.22.3 Operands NOM_CHAM/NOM_CMP/NOM_VARI

```
♦    NOM_CHAM  = nomcham
◊    NOM_CMP   = nomcmp
◊    NOM_VARI  = nomvari
```

These operands make it possible to define the field post-to be treated (NOM_CHAM) like its components given by their name (NOM_CMP) or, for the internal variables, the name of those (instead of V1, V2,…). One can define only 20 components to the maximum by occurrence of the keyword factor OBSERVATION. One can post-treat the fields left by default by the operator (see §3.25 and documentation [U4.53.01] for DYNA_NON_LINE) or to ask for the exit of other fields (for the moment, only EPSI_ELGA). For other fields, it is necessary to make a request of evolution. Selection for NOM_VARI function only for fields of the type VARI_ELGA.

3.22.4 Operands ALL/NOEUD/GROUP_NOEUD/MAILLE/GROUP_MA

```
◊    /TOUT        =   'NOT'                        [DEFECT]
                      'YES'
     /NODE    =   No                           [No]
     /GROUP_NO    =   grno                         [grno]
     /MAILLE      =   lma                          [my]
     /GROUP_MA    =   lgrma                        [grma]
```

These operands make it possible to define the geometrical support of postprocessing:
*   for fields with the nodes ('DEPL', 'QUICKLY', 'ACCE', 'DEPL_ABSOLU', 'VITE_ABSOLU', 'ACCE_ABSOLU', 'CONT_NOEU', 'FORC_NODA'), one extracts the list from the nodes.
*   for fields at the points of Gauss ('SIEF_ELGA' , 'VARI_ELGA'), one extracts the list from the meshs.

Attention not to be used TOUT=' OUI' on large grids!

3.22.5 Observation of a field ELGA

```
◊    EVAL_CMP =   /'VALE ',                        [DEFECT]
                  / 'FORMULA'
◊    FORMULA  =   forms                            [ formule_aster ]
```

One starts by choosing the components or the formula between the components:
*   If EVAL_CMP = ' VALE ' , one extracts simply the list from the components given by NOM_CMP or NOM_VARI .
*   If EVAL_CMP = 'FORMULA' , one evaluates the formula given by thesimple one FORMULA .

If one applies a formula to the components, one will thus have a value and thus an observation, if not, one will have as many observations as components in the list NOM_CMP or NOM_VARI .

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```
◊    EVAL_ELGA      =   /'VALE ',                    [DEFECT]
                        /' MIN ',
                        /' MAX ',
♦    /POINT         =   pi                           [I]
◊    /SOUS_POINT    =   spi                          [I]
```

Once evaluated the components or the formula on the components, one can:
- To extract these values on the points and under-points from integration with EVAL_ELGA = ' VALE '. In this case, it is necessary to explicitly clarify the point and the under-point of integration by NOT and SOUS_POINT . The under-points of integration appear for the elements of structures (beams, plates, hulls, pipes, etc).
- To ask to extract the maximum EVAL_ELGA = 'MAX' or minimum EVAL_ELGA = 'MIN' on all the points and under-points of a mesh.

If one explicitly asks a point and for a under-point, one achievements as of points requested, will have multiplied as many by the component count requested. On the other hand, if one asks the maximum or for the minimum, there is will have only one observation per component requested.

```
◊    EVAL_CHAM     =   /'VALE',                      [DEFECT]
                        /'MIN',
                        /'MAX',
                        /'MOY',
                        /'MINI_ABS',
                        /'MAXI_ABS',
```
'MINI_ABS ' is the minimal value in absolute: MINI_ABS (- 1,3,4, - 12, - 0.1) = 0.1
'MAXI_ABS' is the maximum value in absolute: MAXI_ABS (- 1,3,4, - 12, - 0.1) = 12
Once evaluated the components (or formulates it on the components), have nsi that the point/under-point of extraction, one can:
- To extract these values on all the meshs with EVAL_CHAM= ' VALE '.
- To ask to extract the maximum EVAL_CHAM= 'MAX', minimum EVAL_CHAM= 'MIN' or the average EVAL_CHAM= 'MOY' .

Example: To extract the maximum of trace from the tensor of the constraints on GROUP_MA=' LOUSE '
```
 trace         = FORMULA (VALE=' 0.333* (SIXX+SIYY+SIZZ) ',
                    NOM_PARA= ('SIXX', 'SIYY', 'SIZZ',));
OBSERVATION   =_F (  NOM_CHAM = ' SIE F_ELGA',
                     GROUP_MA = 'LOUSE',
                     EVAL_CHAM = 'MAX',
                     NOM_CMP = ('SIXX', 'SIYY', 'SIZZ',),
                     EVAL_CMP = 'FORMULA',
                     FORMULA = trace,
                     EVAL_ELGA = 'MAX')
```

3.22.6 Observation of a field NOEU

```
◊    EVAL_CMP =   /' VALE ',                          [DEFECT]
                   / 'FORMULA'
◊    FORMULA  =   forms                               [ formule_aster ]
```

One starts by choosing the components or the formula between the components:
- If EVAL_CMP = 'VALE' , one extracts simply the list from the components given by NOM_CMP
- If EVAL_CMP = 'FORMULA' , one evaluates the formula given by thesimple one FORMULA .
If one applies a formula to the components, one will thus have a value and thus an observation, if not, one will have as many observations as components in the list NOM_CMP .

```
◊    EVAL_CHAM    =   /' VALE ',                      [DEFECT]
```

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```
                      / 'MIN',
                      / 'MAX',
                      / 'MOY',
```

Once evaluated the components (or formulates it on the components), one can:
- To extract these values on all the meshs with EVAL_CHAM= ' VALE '.
- To ask to extract the maximum EVAL_CHAM= 'MAX', minimum EVAL_CHAM= 'MIN' or the average EVAL CHAM= 'MOY' .

Example: To extract the maximum of component DX displacement on GROUP_ NO = ' LOUSE '
```
OBSERVATION  =_F (  NOM_CHAM = ' DEPL ',
                    GROUP_ NO = 'LOUSE',
                    EVAL_CHAM = 'MAX',
                    NOM_CMP = ('DX ',),
               )
```

3.22.7 Observation of a field ELEM

```
◊   EVAL_CMP =   / 'VALE ',                          [DEFECT]
                 / 'FORMULA'
◊   FORMULA  =   forms                              [ formule_aster ]
```

One starts by choosing the components or the formula between the components:
- If EVAL_CMP = 'VALE', one extracts simply the list from the components given by NOM_CMP.
- If EVAL_CMP = 'FORMULA' , one evaluates the formula given by thesimple one FORMULA .
If one applies a formula to the components, one will thus have a value and thus an observation, if not, one will have as many observations as components in the list NOM_CMP.

```
◊   EVAL_CHAM   =   / 'VALE',                        [DEFECT]
                    / 'MIN',
                    / 'MAX',
                    / 'MOY',
                    / 'MINI_ABS',
                    / 'MAXI_ABS',
```
'MINI_ABS ' is the minimal value in absolute: MINI_ABS (- 1,3,4, - 12, - 0.1) = 0.1
'MAXI_ABS' is the maximum value in absolute: MAXI_ABS (- 1,3,4, - 12, - 0.1) = 12
Once evaluated the components (or formulates it on the components), have nsi that the point/under-point of extraction, one can:
- To extract these values on all the meshs with EVAL_CHAM= ' VALE '.
- To ask to extract the maximum EVAL_CHAM= 'MAX', minimum EVAL_CHAM= 'MIN' or the average EVAL_CHAM= 'MOY' .

3.22.8 Contents of the table

The table will contain to the maximum 16 columns.

NOM_OBSERVATION	K80	Name given automatically or by the key word TITRATES
TYPE_OBJET	K16	The table thus contains only actual values R
NOM_SD	K24	``
NUME_REUSE	I	Index of re-use of the table in the event of REUSE
NUME_OBSE	I	Sequence number of the observation
INST	R	Moment of the observation
NOM_CHAM	K16	Name of the field observed
EVAL_CHAM	K8	Type of evaluation of the field

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NOM_CMP	K8	Name of the component observed
NOM_VARI	K16	Name of the internal variable observed
EVAL_CMP	K8	Type of evaluation of the component
NODE	K8	Node where is carried out the observation (field with the nodes)
MESH	K8	Mesh where is carried out the observation (field with the meshs)
EVAL_ELGA	K8	Type of evaluation of the fields at the points of Gauss
NOT	I	Not integration where is carried out the observation (fields with the meshs)
SOUS_POINT	I	Under-point of integration where is carried out the observation (fields with the meshs)
VALE	R	Value

The parameter NUME_REUSE is useful in the event of enrichment of the structure of data result. Indeed, if the recovery crushes old sequence numbers in the structure of data result (see keyword ETAT_INIT), it is not the case of the values in the table of observation, which is never modified retroactively. One can thus have two different values for the same moment in the table, the distinction will be done then on NUME_REUSE.

3.23 Keyword HHO

```
◊   HHO              =  _ F (
  ◊    OPTIMIZATION  =/'MEMORY',                    [DEFECT]
                      /'TIME'
  ◊    STABILIZATION = /'CAR',                      [DEFECT]
                      / ' HANDBOOK '
  {If STABILIZATION= 'HANDBOOK'
     ◊  COEF_STAB     =  coeff                      [R]
  }
```

This keyword factor makes it possible to personalize Lbe parameters used by methods HHO during the resolution in STAT_NON_LINE.

3.23.1 Operand OPTIMIZATION

```
◊    OPTIMIZATION = / 'MEMORY',                    [DEFECT]
                    / ' TIME '
```

operators gradient and of stabilization can be precalculated upstream resolution in order to save in times computing to the detriment of consumption memory. The operand 'TIME' carry out this precalculation whereas the operand 'MEMORY' disables (the operators will be recomputed with each iterations of Newton from where a blow of higher calculation).

3.23.2 Operand STABILIZATION

```
◊    STABILIZATION = /'CAR',                         [DEFECT]
                     / ' HANDBOOK '
   {If STABILIZATION= 'HANDBOOK'
      ◊  COEF_STAB     =  coeff                      [R]
   }
```

Methods HHO must be stabilized in order to find the coercity of the discrete problem. The magnitude of stabilization depends on a parameter which is left with the choice of the user. The operand 'CAR' allows automatically to calculate a value of this parameter. This parameter is equal

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to 10*E_moy where E_moy is the median value of the Young modulus in the element. The user can also give itself the value of parameter thanks to the operand 'HANDBOOK' (the value of the parameter of stabilization is indicated in COEF_STAB who must be strictly positive).

3.24 Keyword SUIVI_DDL

◊ SUIVI_DDL =_F ()

This keyword makes it possible post-to treat certain fields with the nodes or the elements on parts of model all the iterations of Newton and to display them in the table of convergence. The simultaneous number of SUIVI_DDL depends on the displayed columns and thus on the activated features.

The keyword factor SUIVI_DDL same syntax has as OBSERVATION for the extraction of the fields, except that one does not give an information about the moments to be extracted, since one carries it out with each iteration of Newton (it does not have the key words there LIST_INST/INST/PAS_OBSE/CRITERE/PRECISION).

◊ TITLE = ltitre,   [list_k]

This keyword expects a list of three chains to the maximum and makes it possible to name the column of the notice board. The chains are truncated with 16 characters.

3.25 Contents of the structure of data EVOL_NOLI

The structure of data EVOL_NOLI the list of the fields filed during calculation (according to the various options of keyword contains FILING). By default, it contains, for each moment, the list of the following fields:
• DEPL : field (with the nodes) of displacements;
• SIEF_ELGA : field (at the points of Gauss) of the constraints;
• VARI_ELGA : field (at the points of Gauss) of the internal variables;
• COMPOR : map of the behavior;
According to certain options of calculation, other fields will be present:
• CONT_NOEU : field (with the nodes) of information on contact-friction (see [U4.44.11] for more details on the contents of this field);
• INDC_ELGA : field (at the points of Gauss) of the statutes of contact for case XFEM with contact;
• COHE_ELGA : field (at the points of Gauss) of the parameter of cohesion for case XFEM with RELATION=' CZM' ;
• SECO_ELGA : field (at the points of Gauss) of the statutes of friction for the case XFEM with contact and friction;

Besides these fields, the structure of data also contains parameters. At every moment, one stores at least:

Name	Keyword origin	Description	Type
INST		Value of the moment of calculation	R
EXCIT	EXCIT	Information on the loadings	K24
MODEL	MODEL	Model	K8
CARAELEM	CARA_ELEM	Elementary characteristics	K8
CHAMPMAT	CHAM_MATER	Material field	K8
PARM_THETA	PARM_THETA	Parameter of integration of the law of behavior	R

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ITER_GLOB		Full number of iterations of Newton	I
CHAR_MINI		Minimum loading reached during the step of time	R
ETA_PILOTAGE		Parameter of piloting	R

When one searches modes of instability (with STAT_NON_LINE or DYNA_NON_LINE) or of the oscillatory modes (with DYNA_NON_LINE only), one stores the field of corresponding displacement and the value of the critical loading or the frequency.

Name	**Keyword origin**	**Description**	**Type**
CHAR_CRIT	CRIT_STAB with TYPE = 'BUCKLING'	Loading criticizes mode of buckling	R
MODE_FLAMB	CRIT_STAB with TYPE = 'BUCKLING'	Mode of buckling	Field of the type DEPL
CHAR_STAB	CRIT_STAB with TYPE = 'STABILITY'	Value of instability	R
MODE_STAB	CRIT_STAB with TYPE = 'STABILITY'	Mode of instability	Field of the type DEPL
FREQ	MODE_VIBR	Frequency of the oscillatory mode (just available in DYNA_NON_LINE)	R
DEPL_VIBR	MODE_VIBR	Oscillatory mode (just available in DYNA_NON_LINE)	Field of the type DEPL

3.26 Keyword MEASURES

◊ TABLE = / 'NOT', [DEFECT]
            / 'YES'
◊ UNIT = links

This order makes it possible to leave information of measurement on calculation:
- maybe in a table of name 'STAT' recoverable by RECU_TABLE (see keyword OBSERVATION)
- maybe in a file with the format CSV the logical unit is given by the keyword UNIT

It should be noted that these measurements also left in the usual file .mess.

3.26.1 Contents of the table or of the generated file

The table is indexed by the step of time: presence of a column 'INST' of real type. Each type of measurement can exist in two forms (simultaneously or not):
- a time CPU (elapse): in this case, the column will contain a reality and will have as a name the type prefixed by Time_ ;
- a number occurrences (for example the iteration count of Newton): in this case, the column will contain an entirety and will have as a name the type prefixed by Count_ ;
- an obstruction memory (vmpeak, out of Mo): in this case the column will contain a entieret will have as a name the type prefixed by Count_ ;

Type of measurement	Time	Occurrences	Description
Compute	Yes	Not	Total computing time

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Lost_Time	Yes	Not	Time "wasted" because of cuttings of the step of time
Time_Step	Yes	Yes	Time and full number of step of time
Newt_Iter	Yes	Yes	Average time of an iteration of Newton per step of time and iteration count per step of time
Blind	Yes	Yes	Time for the filing and many filings on the whole
Post	Yes	Yes	Time taken for postprocessing (buckling,…) and many postprocessings on the whole
Integrate	Yes	Yes	Time for the integration of the behavior and many integrations of behavior per step of time
Factor	Yes	Yes	Time for the factorization of the matrix and many factorizations per step of time
2nd_Member	Yes	Yes	Time for the construction of the second member and many constructions per step of time
Solve	Yes	Yes	Time for the resolution of the linear systems and many resolutions per step of time
Cont_Geom	Yes	Yes	Number of geometrical reactualizations and time spent in pairing for the contact
Cont_Algo	Yes	Yes	Iteration count of contact and time spent in the resolution (discrete methods)
Cont_Prep	Yes	Yes	Many preparations of the contact and time spent in these preparations (for continuous method: creation of the elements, creation and filling of the etc, inlet limit)
Cont_Elem	Yes	Yes	Number and time spent in elementary calculations for the contact (method continues)
Matr_Asse	Yes	Not	Time spent in the creation of the matrices
Cont_NCont	Not	Yes	Number of nodes/points/patchs in contact
Cont_NFric	Not	Yes	Number of nodes/points/patchs in friction
LineSearch	Not	Yes	Iteration count of linear research
Cont_Cycl1	Not	Yes	Many cyclings of type contact (see R5.03.52)
Cont_Cycl2	Not	Yes	Many cyclings of type slip/adherence (see R5.03.52)
Cont_Cycl3	Not	Yes	Many cyclings of type slip before/back (see R5.03.52)
Cont_Cycl4	Not	Yes	Many cyclings of the flip type/failure (continuous method, to see R5.03.52)
Other	Yes	Not	Time spent in the other operations that those measured above
Memory	Not	Yes	Obstruction memory out of Mo

Examples:
- Parameter `Count_Cont_NCont` : many nodes in contact;
- Parameter `Time_Factor` : time spent in factorization.

3.27 Operand **INFORMATION**

◊ INFORMATION = inf

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

3.28 Operand TITLE

◊   TITLE = tx

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