Code_Aster

Version 13

Titre : Opérateur DEFI_CONTACT
Responsable : KUDAWOO Ayaovi-Dzifa

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Operator `DEFI_CONTACT`

1   Goal

To affect conditions of unilateral contact and friction in mechanics or conditions unilateral on the degrees of freedom.

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2   Syntax

```
char_contact = DEFI_CONTACT
(
♦   MODEL           =   Mo,                                      [model]
◊   INFORMATION         =   /1,
    [DEFECT]
                        /2,


♦   FORMULATION     =   /'DISCRETE'                              [DEFECT]
                        /'CONTINUES'
                        /'XFEM'
                        /'LIAISON_UNIL'
```

For the formulations of contact-friction
```
{If FORMULATION   ! = ' LIAISON_UNIL'
    ◊   FRICTION  =  /'WITHOUT',                                [DEFECT]
                     /'COULOMB',
```

Parameters generals for the contact with a grid
```
{If FORMULATION   == 'DISCRETE' or FORMULATION   == 'CONTINUES'}
    ◊   STOP_INTERP     =   /'NOT',                             [DEFECT]
                            /'YES'
    ◊   SMOOTHING       =   /'NOT',                             [DEFECT]
                            /'YES',
    ◊   VERI_NORM       =   /'YES',                             [DEFECT]
                            /'NOT',
}
```

Parameters generals for contact XFEM
```
{If FORMULATION   == 'XFEM'}
    ◊   ELIM_ARETE      =   /'DUAL',                            [DEFECT]
                            /'ELIM'
}
```

Controls geometrical non-linearity
```
{If == FORMULATION 'CONTINUES'
    ◊   ALGO_RESO_GEOM  =   /'POINT_FIXE',                      [DEFECT]
                            /'NEWTON',
}
{If FORMULATION == 'DISCRETE' or (== FORMULATION 'CONTINUES' and ALGO_RESO_GEOM
==' POINT_FIXE')
    ◊   REAC_GEOM       =   /'AUTOMATIC',                       [DEFECT]
                            /'CONTROL',
                            /'WITHOUT'
    {If REAC_GEOM == 'AUTOMATIC'
        ◊   ITER_GEOM_MAXI  =  /10,                             [DEFECT]
                               /iter_geom_maxi,                 [I]
        ◊   RESI_GEOM       =  /0.01,                           [DEFECT]
                               /resi_geom,                      [R]
    }
    {If REAC_GEOM == 'CONTROL'
        ◊   NB_ITER_GEOM    =   /2,                             [DEFECT]
                                /nb_iter_geom,                  [I]
    }
}
{ If (== FORMULATION 'CONTINUES' and ALGO_RESO_GEOM == 'NEWTON')
```

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```
        ◊   RESI_GEOM       =  /0.000001,                    [DEFECT]
                               /resi_geom,                   [R]
    }
    {If FORMULATION == 'XFEM'
        ◊   REAC_GEOM       =  /'WITHOUT',                   [DEFECT]

                               /'AUTOMATIC',
                               /'CONTROL',
        {If REAC_GEOM == 'AUTOMATIC'
           ◊   ITER_GEOM_MAXI  =  /10,                       [DEFECT]
                               /iter_geom_maxi,              [I]
           ◊   RESI_GEOM       =  /0.0001,                   [DEFECT]
                               /resi_geom,                   [R]
        }
        {If REAC_GEOM == 'CONTROL'
           ◊   NB_ITER_GEOM    =  /2,                        [DEFECT]
                               /nb_iter_geom,                [I]
        }
    }


  # Controls non-linearity of contact
    {If FORMULATION == 'DISCRETE'
       ◊   ITER_CONT_MULT  =  /4,                            [DEFECT]
                               /iter_cont_mult,              [I]
    }
    {If 'CONTINUOUS' == FORMULATION or FORMULATION == 'XFEM'
        {If == FORMULATION 'CONTINUES'
           ◊   ALGO_RESO_CONT  =  /'NEWTON',                 [DEFECT]
                               /'POINT_FIXE',
        }
        {If (== FORMULATION 'CONTINUES' and ALGO_RESO_CONT == 'POINT_FIXE') or
    FORMULATION == 'XFEM'
           ◊   ITER_CONT_TYPE  =  /'MAXIMUM',                [DEFECT]
                               /'MULT'

            {If ITER_CONT_TYPE   == 'MULT'
              ◊   ITER_CONT_MULT  =  /4,                     [DEFECT]
                               /iter_cont_mult,              [I]
            }
            {If ITER_CONT_TYPE   == 'MAXIMUM'
              ◊   ITER_CONT_MAXI  =  /30,                    [DEFECT]
                               /iter_cont_maxi,              [I]
            }
        }
    }


  # Controls non-linearity of threshold of friction
    { If FRICTION ==  'COULOMB'
        {If FORMULATION   == 'CONTINUES'
           ◊   ALGO_RESO_FROT  =  /'NEWTON',                 [DEFECT]
                               /'POINT_FIXE',
        }
        {If (== FORMULATION 'CONTINUES' and ALGO_RESO_FROT == 'POINT_FIXE') or
    FORMULATION == 'XFEM'
           ◊   ITER_FROT_MAXI  =  /10,                       [DEFECT]
                               /iter_frot_maxi,              [I]
           ◊   RESI_FROT       =  /0.0001,                   [DEFECT]
                               /resi_frot,                   [R]
        }
```

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```
{If (== FORMULATION 'CONTINUES' and ALGO_RESO_FROT == 'NEWTON')
    ◊  RESI_FROT        =  /0.0001,                        [DEFECT]
                           /resi_frot,                     [R]
    }


}


# Parameters generals of the discrete formulations
{If FORMULATION  == 'DISCRETE'
    # dualized Methods (CONSTRAINT)
    ◊   STOP_SINGULIER  =  /'YES',                         [DEFECT]
                           /'NOT'
    ◊   NB_RESOL        =  /10,                            [DEFECT]
                           /nb_resol                       [I]


    # Method 'GCP'
    ◊   RESI_ABSO       =  /resi_abso                      [R]
    ◊   ITER_GCP_MAXI   =  /0,                             [DEFECT]
                           /iter_gcp_maxi
    ◊   RECH_LINEAIRE   =  /'ACCEPTABLE',                  [DEFECT]
                           /'NON_ADMISSIBLE'
    ◊   PRE_COND        =  /'WITHOUT',                     [DEFECT]
                           /'DIRICHLET'
    {If PRE_COND == 'DIRICHLET'
        ◊   ITER_PRE_MAXI   =  /0,                         [DEFECT]
                               /iter_pre_maxi
        ◊   COEF_RESI       =  /-1. ,                      [DEFECT]
                               /coef_resi                  [R]
    }
}


# Assignment of the case DISCRETE
{If FORMULATION   ==  'DISCRETE'
    ZONE = _F (
        ♦  GROUP_MA_MAIT = grma_mait                       [gr_maille]
        ♦  GROUP_MA_ESCL= grma_escl                        [gr_maille]

        ◊   SANS_GROUP_NO    = l_sgrno                     [l_gr_noeud]
        ◊   SANS_GROUP_MA    =  l_sgrma                    [l_gr_maille]

        ◊   PAIRING       = /'MAIT_ESCL'                   [DEFECT]
                            /'NODAL'

        ◊   NORMAL        = /'MAIT'                        [DEFECT]
                            /'MAIT_ESCL'
                            /'ESCL'

        ◊   VECT_MAIT     =  /'CAR'                        [DEFECT]
                             /'FIXES'
                             /'VECT_Y'
        {If VECT_MAIT == 'FIXES'
            ♦   MAIT_FIXE    =  (Yx, Yy, Yz)               [R]
        }
        {If VECT_MAIT == 'VECT_Y'
            ♦   MAIT_VECT_Y =  (Yx, Yy, Yz)               [R]
        }

        ◊   VECT_ESCL =  /'CAR'                            [DEFECT]
                         /'FIXES'
```

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```
                          /'VECT_Y'
        {If VECT_ESCL == 'FIXES'
             ♦   ESCL_FIXE    =  (Yx, Yy, Yz)                      [R]
        }
        {If VECT_ESCL== 'VECT_Y'
             ♦   ESCL_VECT_Y  =  (Yx, Yy, Yz)                      [R]
        }

        ◊   TYPE_PROJECTION =  /'ORTHOGONAL'                   [DEFECT]
                               /'FIXES'
        { If TYPE_PROJECTION == 'FIXES'
             ♦   DIRE_APPA    =  (Yx, Yy, Yz)                      [R]
        }

        ◊   DIST_POUTRE    =  /'NOT'                          [DEFECT]
                              /'YES'
        ◊   DIST_COQUE      =  /'NOT'                          [DEFECT]
                              /'YES'
        {If DIST_POUTRE ==   'YES' or DIST_COQUE == 'YES'
             ♦   CARA_ELEM =  carac                           [cara_elem]
        }

        ◊   DIST_MAIT      =  dist_mait                       [function]
        ◊   DIST_ESCL      =  dist_escl                       [function]

        ◊   DIST_APPA      =  /-1.0                           [DEFECT]
                              /dist_appa                       [R]
        ◊   TOLE_PROJ_EXT  =  /0.50                           [DEFECT]
                              /tole_proj_ext                   [R]
```

Desactivation of the resolution

```
        ◊   RESOLUTION     =  /'YES'                          [DEFECT]
                              /'NOT'
        {If RESOLUTION == 'NOT'
             ◊   TOLE_INTERP    =  /0. ,                      [DEFECT]
                                   /tole_interp                [R]
        }

        ♦   ALGO_CONT       =  /'CONSTRAINT'                  [DEFECT]
                               /'GCP'
                               /'PENALIZATION'

        {If ALGO_CONT == 'FORCED'
             ◊   SLIDE       =  /'NOT'                        [DEFECT]
                                /'YES'
             {If SLIDE ==   'YES'
                  ◊   ALARME_JEU  =  /0                       [DEFECT]
                                     /alarme_jeu               [R]
             }
        }

        {If ALGO_CONT == 'PENALIZATION'
             ♦   E_N          =  e_n                          [R]
        }

        {If FRICTION ==   'COULOMB'
             ♦   COULOMB      =   Coulomb                     [R]
             ◊   COEF_MATR_FROT =  /0.                        [R]
                                   /coef_matr_frot
```

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```
                ♦  ALGO_FROT        =  /'PENALIZATION'              [DEFECT]
                {If ALGO_FROT == 'PENALIZATION'
                     ♦  E_T        =  e_t                           [R]
                }
            }
        }

    # Assignment of the case CONTINUOUS
    {If FORMULATION   == 'CONTINUES'
        ZONE = _F (
            {  If ALGO_CONT == ' LAKE '
                ♦  GROUP_MA_MAIT   =   grma_mait                    [gr_maille]
                ♦  GROUP_MA_ESCL   =   grma_escl                    [gr_maille]
                ◊  PAIRING       =  /' MORTAR '                     [DEFECT]
                ◊  TYPE_APPA       =  /'RAPID'                      [DEFECT]
                                      /'ROBUST'
                ◊  RESI_APPA       =  /1.0E-8                       [DEFECT]
                                      /resi_appa                    [R]
                ◊  TYPE_JACOBIEN   =  /'INITIAL'                    [DEFECT]
                                      /'BRING UP TO DATE'
                ◊  INTEGRATION     =  /'CAR'                        [DEFECT]
                ◊  CONTACT_INIT    =  /'INTERPENETRATES'            [DEFECT]
                                      /'YES'
                                      /'NOT'
            }
            {  If ALGO_CONT  ! = ' LAKE '
                ♦ GROUP_MA_MAIT =  grma_mait                       [gr_maille]
                ♦ GROUP_MA_ESCL=   grma_escl                       [gr_maille]
                ◊  SANS_GROUP_NO    =  l_sgrno                      [l_gr_noeud]
                ◊  SANS_GROUP_MA    =  l_sgrma                      [l_gr_maille]

                ◊  PAIRING       =  /'MAIT_ESCL'                    [DEFECT]

                ◊  NORMAL        =  /'MAIT'                         [DEFECT]
                                    /'MAIT_ESCL'
                                    /'ESCL'

                ◊  VECT_MAIT       =  /'CAR'                        [DEFECT]
                                      /'FIXES'
                                      /'VECT_Y'
                {If VECT_MAIT == 'FIXES'
                    ♦  MAIT_FIXE   =  (Yx, Yy, Yz)                  [R]
                }
                {If VECT_MAIT == 'VECT_Y'
                    ♦  MAIT_VECT_Y  =  (Yx, Yy, Yz)                 [R]
                }

                ◊  VECT_ESCL =  /'CAR'                              [DEFECT]
                                /'FIXES'
                                /'VECT_Y'
                {If VECT_ESCL == 'FIXES'
                    ♦  ESCL_FIXE   =  (Yx, Yy, Yz)                  [R]
                }
                {If VECT_ESCL== 'VECT_Y'
                    ♦  ESCL_VECT_Y  =  (Yx, Yy, Yz)                 [R]
                }
                ◊  TYPE_PROJECTION =  /'ORTHOGONAL'                 [DEFECT]
                                      /'FIXES'
                {If TYPE_PROJECTION  == 'FIXES'
```

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```
        ♦  DIRE_APPA   =  (Yx, Yy, Yz)                [R]
}

◊   DIST_POUTRE     =  /'NOT'                         [DEFECT]
                       /'YES'
◊   DIST_COQUE      =  /'NOT'                         [DEFECT]
                       /'YES'
{If DIST_POUTRE ==    'YES' or DIST_COQUE == 'YES'
   ♦  CARA_ELEM = carac                          [cara_elem]
}

◊   DIST_MAIT       =  dist_mait                      [function]
◊   DIST_ESCL       =  dist_escl                      [function]

◊   DIST_APPA       =  /-1.0                          [DEFECT]
                       /dist_appa                     [R]
◊   TOLE_PROJ_EXT   =  /0.50                          [DEFECT]
                       /tole_proj_ext                 [R]
# Desactivation of the resolution
◊   RESOLUTION      =  /'YES'                         [DEFECT]
                       /'NOT'
{If RESOLUTION == 'NOT'
        ◊   TOLE_INTERP    =  /0. ,                   [DEFECT]
                              /tole_interp            [R]
}

◊   SLIDE        =  /'NOT'                         [DEFECT]
                    /'YES'
◊   CONTACT_INIT    =  /'INTERPENETRATES'             [DEFECT]
                       /'YES'
                       /'NOT'

◊   INTEGRATION     =  /'CAR'                         [DEFECT]
                       /'GAUSS'
                       /'SIMPSON'
                       /'NCOTES'

{If INTEGRATION ==    'GAUSS'
   ◊   ORDRE_INT    =  /3                             [DEFECT]
                       /1≤ordre_int ≤6                [I]
}
{If INTEGRATION ==    'SIMPSON'
   ◊   ORDRE_INT    =  /1                             [DEFECT]
                       /1≤ordre_int ≤4                [I]
}
{If INTEGRATION ==    'NCOTES'
   ◊   ORDRE_INT    =  /3                             [DEFECT]
                       /3≤ordre_int ≤8                [I]
}
◊   ALGO_CONT       =  /'STANDARD'                    [DEFECT]
                       /'PENALIZATION'
                       /'LAKE'
◊   ADAPTATION      =   /'CYCLING'                    [DEFECT]
                       /'ADAPT_COEF'
                       /'ALL'
                       /'NOT'

{If ALGO_CONT ==  'STANDARD'
   ◊   COEF_CONT    =  /100.                          [DEFECT]
```

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```
                              /coef_cont                   [R]
            }
         {If ALGO_CONT ==   'PENALIZATION'
              ♦   COEF_PENA_CONT= coef_pena_cont           [R]
            }
          }

      {If FRICTION == 'COULOMB'
          ♦   COULOMB       =  Coulomb                     [R]
          ◊   SANS_GROUP_NO_FR   =  l_sgrno                [l_gr_noeud]
          {If SANS_GROUP_NO_FR! =None
              ◊   DIRE_EXCL_FROT      =  (Yx, Yy, Yz)      [R]
          }

          ◊   SEUIL_INIT       =  /0.                      [DEFECT]
                                  /seuil_init              [R]

          ◊   ALGO_FROT        =  /'STANDARD'              [DEFECT]
                                  /'PENALIZATION'

          {If ALGO_FROT 'STANDARD' ==
              ◊   COEF_FROT   =  /100.                     [DEFECT]
                                 /coef_frot                [R]
          }
          {If ALGO_FROT ==   'PENALIZATION'
              ♦     COEF_PENA_FROT  =  /coef_pena_frot     [R]
          }
        }
      }
    }

    # Assignment of the case XFEM
    {If FORMULATION==' XFEM'
       ZONE = _F (
          ♦   FISS_MAIT        =  fiss_mait                [fiss_xfem]
          ◊   INTEGRATION      =  /'NODE'
                                  /'GAUSS'                 [DEFECT]
                                  /'SIMPSON'
                                  /'NCOTES'
          {If INTEGRATION ==     'GAUSS'
             ◊   ORDRE_INT    =  /6                        [DEFECT]
                                 /1≤ordre_int ≤6           [I]
          }
          {If INTEGRATION ==     'SIMPSON'
             ◊   ORDRE_INT    =  /1                        [DEFECT]
                                 /1≤ordre_int≤4            [I]
          }
          {If INTEGRATION ==     'NCOTES'
             ◊   ORDRE_INT    =  /3                        [DEFECT]
                                 /3≤ordre_int ≤8           [I]
          }
          ◊   CONTACT_INIT     =  /'NOT'                   [DEFECT]
                                  /'YES'
          ◊   ALGO_LAGR        =  /'CAR'                       [DEFECT]
                                  /'VERSION1'
                                  /'VERSION2'
                                  /'VERSION3'
                                  /'NOT'
          ◊   TOLE_PROJ_EXT    =  /0.50                    [DEFECT]
                                  /tole_proj_ext           [R]
```

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```
        ◊   ALGO_CONT        = /'STANDARD'                      [DEFECT]
                               /'PENALIZATION'
                               /'CZM'


        {If ALGO_CONT ==  'STANDARD'
            ◊   COEF_CONT     = /100.                           [DEFECT]
                                /coef_cont                      [R]
        }
        {If ALGO_CONT ==  'PENALIZATION'
            ♦   COEF_PENA_CONT  =  /coef_pena_cont              [R]
        }
        { If ALGO_CONT == 'CZM'
            ♦   RELATION        =  /'CZM_EXP_REG'               [DEFECT]
                                   /'CZM_LIN_REG'
                                   /'CZM_OUV_MIX'
                                   /'CZM_TAC_MIX'
                                   /'CZM_LIN_MIX'
        }

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


        {If == 'COULOMB'
            ♦   COULOMB         =  Coulomb                      [R]
            ◊   SEUIL_INIT      = /0.                           [DEFECT]
                                  /seuil_init                   [R]
            ◊   ALGO_FROT       = /'STANDARD'                   [DEFECT]
                                  /'PENALIZATION'

            {If ALGO_FROT ==  'STANDARD'
                ◊     COEF_FROT    = /100.                      [DEFECT]
                                     /coef_frot                 [R]
            }
            {If ALGO_FROT == 'PENALIZATION'
                ♦     COEF_PENA_FROT  =  /coef_pena_frot        [R]
            }
        }
    }


    # Assignment of the case LIAISON_UNIL
    {If FORMULATION   == 'LIAISON_UNIL'
        ZONE=_F (
            ♦  /GROUP_NO        = l_grno                        [l_gr_noeud]
               /GROUP_MA        = l_grma                        [l_gr_maille]
            ♦  NOM_CMP          = l_cmp                         [l_TXM]
            ♦  COEF_IMPO        = l_c_impo                      [function]
            ♦  COEF_MULT        = l_c_mult                      [l_fonction]
            ◊  SANS_GROUP_NO    = l_sgrno                       [l_gr_noeud]
        )
    }
);
```

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3   Principles

This order makes it possible to describe the zones subjected to conditions of unilateral contact with or without friction. Description is done on two levels:

- Total parameters like the choice of the formulation or the parameters of control of the non-linear algorithm of resolution (loops of fixed point or Newton, parameters specific for the solvor);
- Local parameters specific to each zone of contact.

The concept resulting from DEFI_CONTACT is then well informed like parameter in the simple keyword CONTACT operators STAT_NON_LINE [U4.51.03] and DYNA_NON_LINE [U4.53.01]. Each zone understands two surfaces being able to make contact which are described by the data of the groups of meshs which constitute them.

The whole of meshs potentially in contact is meshs of skin: surface and linear in dimension 3 (QUAD9, QUAD8, QUAD4, TRIA7, TRIA6, TRIA3, SEG3, SEG2), linear and specific in dimension 2 (SEG3, SEG2 and POI1).

In dimension 2, meshs of the type POI1 must obligatorily be on surface slave. They are not usable with the formulation CONTINUOUS.

In dimension 3, meshs of the type SEG2 or SEG3 must obligatorily be on surface slave. That implies that the definition of a contact between two elements beam is not possible in 3D .

Caution:

- *For the formulation DISCRETE, in dimension 3, treatment of the contact with quadratic meshs of edge of type QUAD8 require to bind the nodes mediums to the nodes tops in order to have correct results. This operation is carried out automatically in the code. Nevertheless, for calculations 3D continuous mediums the use of elements HEXA27 or PENTA18 (with faces QUAD9) is **strongly advised**.*

  If however the use of elements HEXA20 prove to be necessary, L be linear relations written automatically on this occasion can be likely to enter in conflict with boundary conditions (in particular of symmetry), this is why it can be necessary to impose the boundary conditions only on the nodes tops of the meshs QUAD8 concerned (one will be able to use the operator DEFI_GROUP for the creation of the group of ad hoc nodes).

- *For the formulation CONTINUOUS, in dimension 3, the use of quadratic meshs of edge of type QUAD8 or TRIA6 curves (i.e. whose nodes mediums are not aligned with the nodes tops) can involve violations of the law of contact. More precisely the contact is then solved on average on each element. In the presence of contact one can thus observe games at the same time slightly positive and negative what can disturb the results close to the zone of contact or calculations of recovery with initial state. For this reason it is **advised** to use elements HEXA27 or PENTA18 (with faces QUAD9) or many linear elements.*

- *One can transform into HEXA27 or PENTA18 a grid made up of meshs HEXA20 or PENTA15 using the operator CREA_MAILLAGE [U4.23.02].*

The studied structures can undergo great slips one compared to the other. There exist four great types of formulations:

1) The discrete formulations (see [R5.03.50]) which correspond with the resolution of the discretized unilateral problem (unknown of displacements and nodal forces). This formulation is accessible *via* FORMULATION=' DISCRETE'. It is usable with or without friction of Coulomb.

2) Formulations on the elements XFEM (see [R7.02.12] for the version small slips and [R5.03.53] for the version great slips) which are a variation of the continuous formulation to the case of elements XFEM. These formulations are accessible *via* FORMULATION=' XFEM'. They are usable with or without friction of Coulomb.

3) The formulation continues (see [R5.03.52]) which is a method of Lagrangian increased written using the mixed variational writing "multiplying displacements/contact pressure/of friction". This

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formulation is accessible *via* FORMULATION=' CONTINUE'. It is usable with or without friction of Coulomb.

4) The formulation of type unilateral connection (FORMULATION=' LIAISON_UNIL'). Near to the discrete formulations, it is pressed on an algorithm used in contact to impose boundary conditions of type inequality on any degree of freedom. This formulation is treated separately in the last part of this document (*cf.* §3.8).

Before doing a calculation with contact, it is **essential** to have read the note of use of the contact [U2.04.04] which clarifies for examples the role of the majority of the keywords described below and described methodologies for various types of studies with taking into account of the contact.

All the methods of resolution of contact-friction known as formulations "with a grid" (discrete formulations [R5.03.50] or formulation continues [R5.03.52]) rest on a strategy in two times:

• an operation of pairing which consists in finding which meshs and which nodes are potentially in situation of contact;
• an operation of resolution itself which consists in solving the problem of unilateral contact with or without friction.

Paragraphs 3.1 and 3.2 concentrate on the phase of pairing while the paragraphs 3.4 and 3.5 methods of resolution of the problem treat.

Finally the paragraph 3.6 described the field dedicated to postprocessing, produced by a calculation with contact.

The formulation 'LIAISON_UNIL' is approached in the paragraph 3.8.

3.1 Control of pairing (methods with a grid except XFEM and LAKE)

♦   ZONE   = _F (*options of pairing*)

The keywords of this paragraph are valid for the formulations with a grid (DISCRETE and CONTINUOUS), except for the method LAKE (see §3.3).

3.1.1 Operand PAIRING

◊   PAIRING   = /'MAIT_ESCL'   [DEFECT]
                  /'NODAL'

In the case of the discrete formulations pairing can be node-facet ('MAIT_ESCL') or nodal ('NODAL'). For nodal pairing one writes a relation of nonpenetration between a main node and a node slave, whereas for pairing node-facet one writes this relation between a node slave and his projection on the mesh Master nearest (see [R5.03.50] for details on the algorithm of pairing).

Nodal pairing is reserved for the compatible grids and is available only in formulation DISCRETE. Master-slave pairing is the only method to make it possible to take into account the great slips in a precise way.

3.1.2 Operands GROUP_MA_MAIT/GROUP_MA_ESCL

♦   GROUP_MA_MAIT = l_grma_mait   [l_gr_maille]
♦   GROUP_MA_ESCL=   l_grma_escl   [l_gr_maille]

For the formulations with a grid the user provides the list of the potential meshs of contact of surface Master (GROUP_MA_MAIT) and of surface slave (GROUP_MA_ESCL). These meshs must be surface or linear in dimension 3 (QUAD9, QUAD8, QUAD4, TRIA7, TRIA6, TRIA3, SEG3, SEG2), linear or specific in dimension 2 (SEG3, SEG2 and POI1).

Caution :

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> – *It is important to check that the connectivity of these meshs is such as **the normal with the structure is outgoing** (with this intention, use MODI_MAILLAGE keyword ORIE_PEAU_2D, ORIE_PEAU_3D, ORIE_NORM_COQUE [U4.23.04]).*
> – *The intersection between surface slave and Master of the same zone must be disjoined or the common nodes must be excluded (cf. 3.1.3).*
> – *Surfaces slaves must be imperatively two to two disjoined in continuous formulation.*

Subsequently, the master-slave concept will be used: the nodes of surface slave cannot "penetrate" in the facets (or the nodes) of surface Master. In the case of the pairing of the type 'MAIT_ESCL', surface Master is that defined by 'GROUP_MA_MAIT'. In the case of the pairing of the type 'NODAL' (available only for the discrete formulations), surface Master is that which must comprise the most nodes. If it is not the case the user is stopped by an error message and guest to invert two surfaces.

Notice :

> • *It is impossible to mix purely two-dimensional modelings (plane constraints C_PLAN, plane deformations D_PLAN and axisymmetric AXIS) with three-dimensional modelings. Surfaces Master and slave must be of comparable nature (2D/2D or 3D/3D). An error message stops the user in the contrary case. Let us note that a beam, a plate or a hull are of dimension 3 and that it is thus possible to make contact poutre/3D or beam/plate.*
> • *In 3D, it is not possible to define zones of contact with a surface slave of the type SEG2 or SEG3 , which excludes the case from a contact between two elements of beams or cables.*

3.1.3   Operands SANS_GROUP_NO/SANS_GROUP_MA

◊   SANS_GROUP_NO   = l_sgrno   [l_gr_noeud]
◊   SANS_GROUP_MA   = l_sgrma   [l_gr_maille]

These operands make it possible to exclude from the nodes of surfaces slaves, operation which is recommended when the latter are subjected to boundary conditions in the expected direction of the contact (embedding for example).

3.1.4   Operands TYPE_PROJECTION/DIRE_APPA

◊   TYPE_PROJECTION = /'ORTHOGONAL'   [DEFECT]
                        /'FIXES'
◊   DIRE_APPA   = (Yx, Yy, Yz)   [R]

The main choice of the mesh paired with a node slave is done by an operation of minimization of the distance between this node and the meshs Masters. With the option by default, TYPE_PROJECTION= 'ORTHOGONAL', the algorithm used for this orthogonal projection is a classical algorithm of Newton.
In very rare cases this algorithm can fail, for example if projection on a mesh is not single, which can arrive if the mesh Master is convex. In this case, the user can inform a fixed direction of pairing to use in the algorithm *via* the option TYPE_PROJECTION= ' FIXE', direction being then given by a vector in DIRE_APPA.

3.1.5   Operands DIST_APPA and TOLE_PROJ_EXT

◊   DIST_APPA   = /-1.0   [DEFECT]
                        /dist_appa   [R]
◊   TOLE_PROJ_EXT   = /0.50   [DEFECT]
                        /tole_proj_ext   [R]

During the pairing of the node current slave, it is possible to restrict the field of research among the meshs Masters with the use of the keyword DIST_APPA. If DIST_APPA=-1 (value by default), then all the meshs Masters given in the zone of contact are likely to be paired with the node slave. If

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DIST_APPA=val with valley a positive reality, then only the meshs Masters located, in 3D in the sphere, 2D in the circle of radius valley centered (E) on the node slave can be paired.

In certain situations, it can be necessary to extend in a fictitious way the meshs of surface Master. Let us take the case of the contact in 2D on Figure 3.1.5-1 (surfaces of contact are thus segments), one places oneself on the edge of the surface of contact. The projection of a node slave falls apart from surface Master.
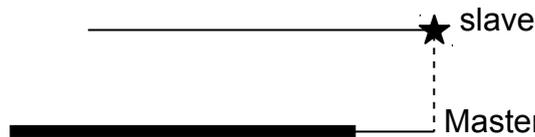
**Figure 3.1.5-1: Projection of a node slave apart
from a mesh Master**

A solution then consists in not pairing the node, which comes down excluding it from the contact:
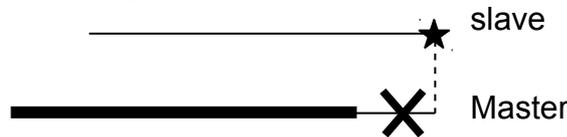
Figure 3.1.5-2: Exclusion of a node slave

However, this solution does not take account of the borderline cases and can cause inopportune interpenetrations if ever the grid is not "optimal" (i.e. not fine enough, which is difficult to ensure within the framework as of great transformations). *A contrario*, one cannot obviously fold back all the nodes projecting itself apart from surface Master.
One thus chose an intermediate solution by limiting the extension of surface Master likely to involve a folding back.
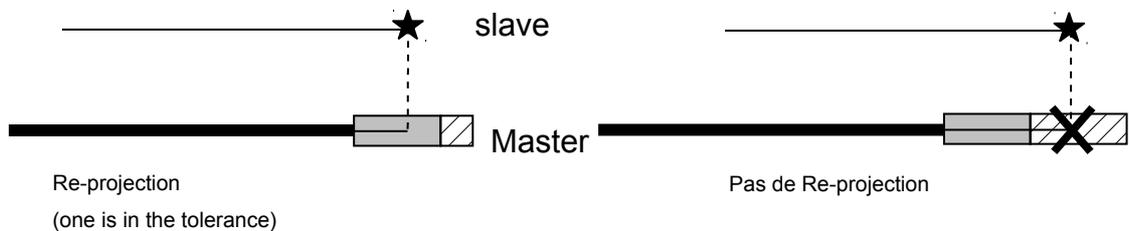
Re-projection

(one is in the tolerance)

Pas de Re-projection

Figure 3.1.5-3: Operation of `TOLE_PROJ_EXT`

The size of the zone of folding back is fixed by the keyword 'TOLE_PROJ_EXT' who takes for argument the value, reported to the element of reference, of the extension of the mesh Master. By default, this value is fixed at 0.50. For example in 2D, that means that any node slave projecting himself with more than 25% on the right or on the left the length of the mesh Master will not be folded back (in the case of a segment, the element of reference is length 2, cf [R3.01.01]). To prohibit the folding back completely, it is enough to fix TOLE_PROJ_EXT negative. This operator is valid in 2D and 3D (in this last case, it is the extension of a surface mesh of contact).

Notice :

> *It is dangerous to disable the folding back completely. Except the edges of surfaces of contact, there exist indeed situations where points are not projected inside any mesh Master (it is the case for any surface convex Master). If all the nodes of contact came to to be excluded, an alarm is emitted. It is then advisable to check that this situation is well that expected by the user.*

3.1.6 Choice of the normals

3.1.6.1 Type of normal (NORMAL)

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```
◊   NORMAL        =  /'MAIT'                              [DEFECT]
                     /'MAIT_ESCL'
                     /'ESCL'
```

It is possible to choose the type of the normal used to write the conditions of not-interpenetration:

*   the normal external with the mesh Master (NORMALE=' MAIT', by default);
*   the interior normal with the mesh slave (NORMALE=' ESCL');
*   an average enters the normals Master and slave (NORMALE=' MAIT_ESCL').

3.1.6.2 Determination of the normals Master or slave (VECT_MAIT/VECT_ESCL)

```
◊   VECT_MAIT     =  /'CAR'                               [DEFECT]
                     /'FIXES'
                     /'VECT_Y'
♦   MAIT_FIXE     =  (Yx, Yy, Yz)                         [R]
♦   MAIT_VECT_Y   =  (Yx, Yy, Yz)                         [R]

◊   VECT_ESCL     =  /'CAR'                               [DEFECT]
                     /'FIXES'
                     /'VECT_Y'
♦   ESCL_FIXE     =  (Yx, Yy, Yz)                         [R]
♦   ESCL _VECT_Y  =  (Yx, Yy, Yz)                         [R]
```

The determination of the normal (on the mesh slave or the mesh Master) can be made several manners:

*   automatically, the normal is then calculated by the use of the functions of form of the element, it is the option 'CAR' ;
*   fixed and data directly by the user, it is the option 'FIXES'. One enters then the normal with the keyword MAIT_FIXE or ESCL_FIXE ;
*   variable and data indirectly by the tangent, it is the option VECT_Y. The user gives the direction then of **second tangent vector** by the keyword MAIT_VECT_Y or ESCL_VECT_Y. The code then reconstitutes the normal starting from the vector product of the first tangent of the mesh and the vector provided by the user.

A direction fixes (option VECT_*=' FIXE') is necessary if one must evaluate the normal on a mesh of the type POI1.

A variable direction given by the second tangent (VECT_MAIT=' VECT_Y') is particularly used in the case of the beams which become deformed only in one plan. In this case, the use of the option of the type VECT_Y allows to reactualize the normal continuously while the beam becomes deformed:

$$\vec{N} = \vec{T} \wedge VECT\_Y$$

Figure 3.1.6.2-1: Determination of the normal by VECT_Y

In the example above, T1= (1,0,0) and T2= (- 1,0,0), with VECT_Y = (0,1,0), one obtains the normal desired for each beam: N1= (0,0,1) and NR2= (0.0, - 1).

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Orientation of each beam (i.e. vectors T1 and T2) is given using the keyword ORIE_LIGNE of the operator MODI_MAILLAGE [U4.23.04].

3.1.6.3 Smoothing of the normals (SMOOTHING)

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

The operand SMOOTHING allows to smooth the normals on the surfaces of contact intervening in the calculation of the matrix of contact. One will note Q an unspecified node of surfaces of contact (main or slave), P a node of surface slave and M the main node obtained by projection of the node P. Smoothing is done in two stages:

- the first stage of smoothing consists in carrying out an average with the node Q normals with the meshs which contain Q ;
- the second stage consists in interpolating the normal in P or M starting from the normals in Q and of the functions of form associated with the mesh containing P or M.

Smoothing takes into account the options of normals decided by the keywords VECT_MAIT and VECT_ESCL. Attention, this parameter is total and not zone.

3.1.7 Modification of the game

The game is always calculated as being the minimal distance between the node slave and projection on the mesh Master nearest, modulo the options of choice of this normal (*cf.* 3.1.6). It is however possible to define values of game "into hard", for example, to simulate the presence of a hole or a bump not represented by the grid, or to take into account the geometrical characteristics of the elements of structure which use the concept of fibre neutral or average surface.

3.1.7.1 Operands DIST_MAIT/DIST_ESCL

◊ DIST_MAIT   = dist_mait   [function]
◊ DIST_ESCL   = dist_escl   [function]

These operands make it possible to take into account a fictitious game nonwith a grid or the thickness of the hulls for example (by defaults the relations of contact are written between the parts with a grid i.e. between the two average layers).
This game is taken into account on surfaces Masters (DIST_MAIT) or slaves (DIST_ESCL). One positively counts the distance in the direction of the outgoing normal to the structure (cf [R5.03.50]). A negative value thus makes it possible "to dig virtually" a surface (Master like slave). Contrary, a positive value makes it possible "to enlarge" a surface.
The well informed sizes are necessarily functions of the variables of space or time ($X, Y, Z, INST$). If the user wishes a fixed value, it must define a constant function (see DEFI_CONSTANTE [U4.31.01]).

3.1.7.2 Operands DIST_POUTRE/DIST_COQUE/CARA_ELEM

◊ DIST_POUTRE   = /'NOT'   [DEFECT]
                    /'YES'
◊ DIST_COQUE   = /'NOT'   [DEFECT]
                    /'YES'
♦ CARA_ELEM   = carac   [cara_elem]

Similar to the two preceding keywords, keywords DIST_POUTRE/DIST_COQUE allow to introduce a fictitious game which rests on the description of the elements of structure in the concept produced by AFFE_CARA_ELEM that the user obligatorily informed:

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- for the elements of beam (modeling POU_*), the keyword DIST_POUTRE stipulate that the code must take account of an additional game corresponding to the ray of the section **circular** beam.
- for the elements of plate or hull (modeling DKT or COQUE_3D for example), the keyword DIST_COQUE stipulate that the code must take account of an additional game corresponding to the half-thickness around the average layer of a hull.

Attention, when these keywords are used, the fictitious game is added only on surface slave. If one models a contact between two elements of structures, it will thus be necessary also to use DIST_MAIT.

3.2   Control of pairing specific to the formulation CONTINUOUS

3.2.1   Operands SANS_GROUP_NO_FR

◊ SANS_GROUP_NO_FR = l_sgrno   [l_gr_noeud]

◊ DIRE_EXCL_FROT   = (Yx, Yy, Yz)   [R]

These keywords make it possible to the user to potentially exclude from the treatment of the friction of the nodes slaves carrying of the boundary conditions in conflict with the imposition of the conditions of adherence and slip. The excluded nodes continue however to check the conditions of contact.
In 2D, no other keyword is necessary: the nodes are excluded from friction.
In 3D, if the user informed a vector with 3 components under the keyword DIRE_EXCL_FROT then the direction indicated by the projection of this vector on the tangent level to the points of contact is excluded. Adherence or the slip will not thus occur more but in the perpendicular direction (in the tangent plan).

If the user does not inform the keyword DIRE_EXCL_FROT in 3D, then that amounts excluding the 2 orthogonal directions from friction and thus more not solving friction on the eliminated nodes.

Notice :

- *The exclusion of nodes is not possible that with the diagram of integration by default (cf § 3.5.2.4)*

3.3   Control specific to the formulation LAKE

♦ ZONE   = _F (*options*)

The keywords of this paragraph are valid for the method LAKE.

3.3.1   Operands GROUP_MA_MAIT/GROUP_MA_ESCL

♦ /GROUP_MA_MAIT   = l_grma_mait   [l_gr_maille]
♦ /GROUP_MA_ESCL   = l_grma_escl   [l_gr_maille]

For Lhas formulation LAKE the user provides the list of the potential meshs of contact of surface Master (GROUP_MA_MAIT) and of surface slave (GROUP_MA_ESCL). Surface slave must be prepared beforehand (cut out in patchs) by the order CREA_MAILLAGE/DECOUPE_LAC.

Caution :

- *It is important to check that the connectivity of these meshs is such as **the normal with the structure is outgoing** (with this intention, use MODI_MAILLAGE keyword ORIE_PEAU_2D, ORIE_PEAU_3D, ORIE_NORM_COQUE [U4.23.04]).*

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–   The intersection between surface slave and Master of the same zone must be disjoined or the common nodes must be excluded (cf. 3.1.3).
–   Surfaces slaves must be imperatively two to two disjoined

3.3.2   OperandS `PAIRINGTYPE_APPA`

```
◊   PAIRING       = /'MORTAR'                          [DEFECT]
◊   TYPE_APPA     = /'ROBUST'                          [DEFECT]
                    /'RAPID'
◊   RESI_APPA     = /1.0E-8                    [DEFECT]
                    /resi_appa                 [R]
```

The method LAKE uses obligatorily a pairing of the type "mortar", i.e. segment/segment (in 2D) or face/face (in 3D). This pairing is much more expensive than a pairing of type node/segment used for the other methods of contact. One thus has the choice between two possibilities:

•   To use a fast algorithm but which is likely to cause false pairings (it is easy to control this problem visually). One chooses then TYPE_APPA   = 'FAST' ;
•   To use a robust algorithm but much slower. One chooses then TYPE_APPA = 'ROBUST ;

One recommends to use "fast" pairing only for the simple cases (related surfaces).
The parameter RESI_APPA allows to regulate the degree of accuracy of pairing. It is not recommended to touch there, its use requires great precautions and must be held to the experts.

3.3.3   Operand `TYPE_JACOBIEN`

```
◊   TYPE_JACOBIEN   = /'INITIAL'                              [DEFECT]
                      /' BRING UP TO DATE '
```

This operand is used when the kinematics of the problem is of type "great transformations". For example, if one makes a simulation with the model " GDEF_LOG ", it is necessary to use TYPE_JACOBIEN='BRING UP TO DATE' , if not the results (as individuals contact pressures) will be slightly false.

3.3.4   Operand `CONTACT_INIT`

```
◊   CONTACT_INIT    = /'INTERPENETRATES'                         [DEFECT]
                      /'YES'
                      /'NOT'
◊   SEUIL_INIT      = /0.                              [DEFECT]
                      /seuil_init                      [R]
```

pérande CONTACT_INIT allows to fix the statute of contact at the initial state.

By defaults, only the connections with null game or interpenetrated are activated by the algorithm (CONTACT_INIT=' INTERPENETRE'). It is nevertheless possible to force the algorithm to activate all the connections without exception (CONTACT_INIT=' OUI'). The value CONTACT_INIT=' INTERPENETRE' is obligatory in the event of resumption of calculation with an initial state. It is also possible to disable any initial contact by CONTACT_INIT=' NON'.

The method LAKE uses a specific SD at exit CONT_ELEM , defined by element (see § 3.7).

3.4   Choice and control of the total algorithm of resolution

3.4.1   Control of geometrical non-linearity

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Whatever the formulation employed, it is necessary to treat the geometrical non-linearity of the problem of contact-friction. It is possible is to neglect it (REAC_GEOM=' SANS'), that is to say to solve it in an approximate way (REAC_GEOM=' CONTRÔLE') or exactly (REAC_GEOM=' AUTOMATIQUE').

To solve this non-linearity, one employs an algorithm of the type in general "not fixes" (ALGO_RESO_GEOM=' POINT_FIXE'). The formulation CONTINUOUS is also able to treat geometrical non-linearity with the centre even of the algorithm of Newton (ALGO_RESO_GEOM=' NEWTON', to see §3.4.4.4).

In formulation XFEM, the choice to activate the geometrical reactualization or not switches towards two distinct formulations (see [R5.03.53]): X-FEM small slips or X-FEM great slips.

When geometrical non-linearity is solved by a loop of "fixed point", a certain number of adjustments are possible:

```
◊   REAC_GEOM      =  /'AUTOMATIC',                    [DEFECT]
                      /'CONTROL',
                      /'WITHOUT'
◊   ITER_GEOM_MAXI =  /10,                             [DEFECT]
                      /iter_geom_maxi,                 [I]
◊   RESI_GEOM      =  /0.01,                           [DEFECT]
                      /0.0001,                         [DEFECT]  (XFEM)
                      /resi_geom,                      [R]
◊   NB_ITER_GEOM   =  /2,                              [DEFECT]
                      /nb_iter_geom,                   [I]
```

The operand REAC_GEOM indicate on which geometrical configuration with the problem of contact is dealt:

- REAC_GEOM=' AUTOMATIQUE' : the geometry automatically is reactualized i.e. that the number of cycles "reactualization geometrical-iterations" until convergence is not fixed by advance but obeys geometrical convergence criteria. It is the option by default, advised to solve the non-linearity of pairing correctly. It ensures that the conditions of contact were imposed on a configuration (initial) which differs from less resi_geom found configuration (1% by default for the formulations DISCRETE or CONTINUOUS, 0.01% by default for the formulation XFEM).

- REAC_GEOM=' SANS' : one works on the initial geometry. This option is valid only on the assumption of small disturbances or when the normal on the surfaces of contact does not change during calculation.

- REAC_GEOM=' CONTRÔLE' : when the automatic criterion does not manage to be satisfied, the user must control itself the geometrical reactualization and for this reason it must inform the parameter NB_ITER_GEOM. It is the number of geometrical cycles of reactualizations which will be carried out by step of load. We place at a step of load given:
    - Value 1 indicates that with convergence of Newton, one reactualizes the geometry and one passes to the step of load according to.
    - Value 2 indicates that with convergence of Newton, one reactualizes the geometry and one reiterates until convergence before passing to the step of load according to.
    - The value $n>2$ indicate that one makes n cycles "reactualization geometrical-convergence" before passing to the step of load according to.

If you selected REAC_GEOM=' AUTOMATIQUE', the parameter ITER_GEOM_MAXI is the tolerated maximum number of geometrical cycles of reactualizations. If the bearing criterion on RESI_GEOM is not satisfied at the end of iter_geom_maxi cycles, then one stops in error or one cuts out the step of time if the user asked it. Documentation [U2.04.04] provides many advices to overcome these problems of convergence (in particular, to activate smoothing).

Remarks :

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- *If the user chooses a reactualization controlled with $n > 1$ and that Code_Aster detects the need for a geometrical reactualization, it will emit an alarm. Load with the user to decide if the made mistake (necessarily higher than 1%) is acceptable or not. There is indeed a risk of error of pairing (a mesh was paired on a configuration which moved) and thus of interpenetration.*
- *If one solves on the initial geometry or with only one cycle of geometrical reactualization, there is no warning because one cannot calculate error. The user must thus check the validity of his choice in postprocessing.*
- *The value of the geometrical convergence criteria is displayed in the table of the iterations of Newton (column* `CONTACT VALUE CRITERION`*).*

3.4.2 Friction

◊   FRICTION   =   /'WITHOUT',   [DEFECT]
                      /'COULOMB',

To assign friction of Coulomb to the zones of contact, use the keyword FRICTION='COULOMB'. This keyword is **total** (valid for all the zones), but it is possible to affect friction zones by zone while exploiting the value of the coefficient of Coulomb (one puts this coefficient at 0 when one does not wish friction).

3.4.3 Formulation DISCRETE

3.4.3.1 Choice of the algorithms

♦   ALGO_CONT   =   /'CONSTRAINT'   [DEFECT]
                       /'GCP'
                       /'PENALIZATION'
♦   ALGO_FROT   =   /'PENALIZATION'   [DEFECT]

To select the type of algorithm in the formulation DISCRETE, the keywords are used ALGO_CONT and ALGO_FROT. ALGO_FROT is modifiable only if FROTTEMENT=' COULOMB'. All the combinations are not possible:

	ALGO_FROT=' PENALISATION'
ALGO_CONT=' CONTRAINTE'	*Impossible*
ALGO_CONT=' GCP'	*Impossible*
ALGO_CONT=' PENALISATION'	*OK*

The various methods of resolution are:

- 'FORCED'   : algorithm prear defect which deals with the problem of the exact unilateral contact with the method of the active constraints (see [R5.03.50]). **Possible Pas de friction**.
- 'GCP'   : it is an iterative method near of the method 'FORCED' but which is particularly adapted to the cases where the number of connections of contact is very high. **Possible Pas de friction**.
- 'PENALIZATION'   : the penalized method makes it possible to treat problems of contact in an approximate way with or without friction, in 2D or 3D.

Although the various algorithms are given by zone, it is not possible to mix several combinations of methods in the same one DEFI_CONTACT.

3.4.3.2 Methods dualized (CONSTRAINT)

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Responsable : KUDAWOO Ayaovi-Dzifa

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Method CONSTRAINT allows to solve problems of contact without friction in an exact way (no interpenetration is tolerated). It is particularly fast and robust, its convergence is proven. The resolution of the system of inequations resulting from the contact being based on explicit construction from a complement from Schur, its use is limited to a few hundreds of connections of contact. Beyond the costs report and calculation become too important.

◊   NB_RESOL   =   /10,   [DEFECT]
                         /nb_resol   [I]

NB_RESOL is the number of simultaneous resolutions for construction of the complement of Schur. To carry out several simultaneous resolutions makes it possible to handle matrices per blocks. To increase nb_resol thus accelerate the construction of the complement of Schur but made lose place memory. nb_resol=10 is a good compromise. This parameter is to be held for **experts**.

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

STOP_SINGULIER allows to disable the fatal error appearing if the complement of Schur is singular following an important loss of decimals in factorization (8 decimals by default). One informs for that STOP_SINGULIER= 'NON'. This parameter is to be held for **experts**.

◊   ITER_CONT_MULT   =   /4,   [DEFECT]
                         /iter_cont_mult,   [I]

One can control the loop on the statutes by giving a multiplying coefficient, ITER_CONT_MULT : the maximum number of iterations on the statute of contact will be equal to the product iter_cont_mult by the number of nodes slaves.

If calculation stops because the maximum number of iterations of contact is exceeded, one can then try to refine the grid, to subdivide the step of time or as a last resort to increase the value of ITER_CONT_MULT.

Note: for the method CONSTRAINT, convergence being proven, this coefficient is fixed into hard at 2.

3.4.3.3 Method SLIDE

◊   SLIDE   =   /'NOT'   [DEFECT]
                         /'YES'
◊   ALARME_JEU   =   /0   [DEFECT]
                         /alarme_jeu   [R]

This option is available only for the method 'CONTRAINTE'. It makes it possible to activate the mode of bilateral contact also called "slide", in which two surfaces being in touch stay "stuck" (i.e. with a null game) whatever the evolution of the loading. It authorizes great relative slips.
The bilateral contact is activated only once surfaces are indeed in contact (one does not stick *a priori* two separate surfaces if the loading does not imply it).
The operand 'ALARME_JEU' allows to set off an alarm as soon as the algorithm detects that, without the method slide, there would be separation of two surfaces. Its value is regulated by default with 0, which alarms the user as soon as surfaces should have fallen apart without the activated option.

3.4.3.4 Method GCP

This method makes it possible to solve problems of contact without friction. It solves with an adjustable precision (possibly very high) the conditions of contact using multipliers of Lagrange. It is in any point similar to the method 'FORCED' with the difference close which it is of completely iterative nature and thus very little rebukes in memory. In other words, the overcost of storage related to the taking into account of the contact is weak. This specificity causes to return it particularly adapted to the case implying a large number of connections of contact.

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◊	RESI_ABSO	=	/resi_abso		[R]
◊	ITER_GCP_MAXI	=	/0		[DEFECT]
			/iter_gcp_maxi		
◊	RECH_LINEAIRE	=	/'ACCEPTABLE'		[DEFECT]
			/'NON_ADMISSIBLE'		
◊	PRE_COND	=	/'WITHOUT',		[DEFECT]
			/'DIRICHLET'		
◊	ITER_PRE_MAXI	=	/0		[DEFECT]
			/iter_pre_maxi		
◊	COEF_RESI	=	/-1.		[DEFECT]
			/coef_resi		[R]

The keyword RESI_ABSO allows to regulate the precision of the resolution of the inequations of contact (it is a criterion of stop on the value of the games for the iterative algorithm). RESI_ABSO (that it is necessary to understand by "absolute residue") represents the maximum level of interpenetration tolerated for the bodies in contact. From a practical point of view, one will start by choosing a value about 10^{-3} time the size of the elements in the vicinity of surfaces of contact then one will decrease this value until stabilization of the results.

The maximum number of authorized iterations of the algorithm of the gradient combined project can be regulated with the keyword ITER_GCP_MAXI. By default this iteration count depends on the size on the problem.

Like any method of iterative resolution, method 'GCP' can be accelerated by the use of a pre-conditioner. Only one is available today and it is about a pre-conditioner of Dirichlet (PRE_COND='DIRICHLET'). Its use can in certain cases accelerate and decrease appreciably the time of resolution. By default no pre-conditioner is activated (PRE_COND = ' SANS').
The phase of prepacking is carried out by the resolution (also iterative) of an auxiliary problem. The keyword COEF_RESI allows to start this pre-conditioner only when the residue sufficiently decreased: more precisely when the initial residue of the algorithm (i.e. initial interpenetration) was multiplied by coef_resi (coef_resi is thus smaller than 1).
ITER_PRE_MAXI allows to fix the maximum number of iterations of the pre-conditioner.

Method of resolution 'GCP' require a phase called linear research. Two alternatives are available: acceptable or not-acceptable. One chooses them with the keyword RECH_LINEAIRE (*cf.* [R5.03.50]).

3.4.3.5 Method PENALIZATION

This method is a method of resolution of the contact/friction by regularization. It is nonexact in the direction where there is **always** interpenetration when the contact is established. If one uses a discrete formulation with penalization, it is thus advisable to inform it (S) coefficient (S) of penalization (cf §3.5.1.1).

3.4.4 Formulation CONTINUOUS

3.4.4.1 Choice of the algorithms

◊	ALGO_RESO_CONT	=	/'NEWTON'	[DEFECT]
			/'POINT_FIXE'	
◊	ALGO_RESO_FROT	=	/'NEWTON'	[DEFECT]
			/'POINT_FIXE'	
◊	ALGO_RESO_GEOM	=	/'POINT_FIXE'	[DEFECT]
			/'NEWTON'	

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The formulation continues has two types of algorithms to solve non-linearities of contact-friction: algorithm of point fixed or algorithm of generalized Newton. In addition to geometrical non-linearity (*cf.* §3.4.1), this choice can be also carried out for the non-linearity of contact and of friction *via* keywords ALGO_RESO_CONT, ALGO_RESO_FROT and ALGO_RESO_GEOM (all the choices are not possible):

ALGO_RESO_CONT	ALGO_RESO_FROT	ALGO_RESO_GEOM	
POINT_FIXE	POINT_FIXE	POINT_FIXE	***OK***
NEWTON	POINT_FIXE	POINT_FIXE	***OK***
POINT_FIXE	NEWTON	POINT_FIXE	***OK***
NEWTON	NEWTON	POINT_FIXE	***OK (by default)***
POINT_FIXE	POINT_FIXE	NEWTON	***Impossible***
NEWTON	POINT_FIXE	NEWTON	***OK***
POINT_FIXE	NEWTON	NEWTON	***Impossible***
NEWTON	NEWTON	NEWTON	***OK***

When one chooses the method of Newton generalized for friction, the produced tangent matrix becomes not-symmetrical. The method of Newton generalized is much faster and less sensitive to the value of the coefficient of friction than the method of point fixed. It can in certain cases prove less robust in the treatment of geometrical non-linearity, this is why it is not activated by default in this case. In the case of the resolution of a problem of contact-friction in generalized Newton, it is often necessary to increase the iteration count of Newton (fixed by default at 10).

Whatever the method of resolution used (not fixes or Newton) the got results are identical.

3.4.4.2 Non-linearity of contact

```
◊   ITER_CONT_TYPE   =  /'MAXIMUM',                    [DEFECT]
                        /'MULT'
◊   ITER_CONT_MULT   =  /4,                            [DEFECT]
                        /iter_cont_mult,               [I]
◊   ITER_CONT_MAXI   =  /30,                           [DEFECT]
                        /iter_cont_maxi,               [I]
```

With the adjustments by default (ALGO_RESO_CONT=' NEWTON'), there is no parameter required for the resolution of the non-linearity of contact.
When one chooses ALGO_RESO_CONT=' POINT_FIXE', one can control the loop on the statutes of contact in two manners:
*   By giving the number **absolute** maximum of iterations of contact, ITER_CONT_TYPE=' MAXI' then ITER_CONT_MAXI ;
*   By giving the number **relative** maximum of iterations of contact by a multiplying coefficient, ITER_CONT_TYPE=' MULT' then ITER_CONT_MULT ; in this case, the iteration count on the statute of contact will be equal to the product iter_cont_mult by the number of nodes slaves.

Into method of point fixed, the statutes are changed per blocks and the maximum number of iterations is thus more logically indicated in absolute value. If the maximum number of iterations of contact is reached, one can then try to refine the grid, to subdivide the step of time or as a last resort to increase the value of ITER_CONT_MAXI/ITER_CONT_MULT.

3.4.4.3 Non-linearity of threshold of friction

```
◊   ITER_FROT_MAXI   =  /10,                           [DEFECT]
                        /iter_frot_maxi,               [I]
```

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```
◊   RESI_FROT      =   /0.0001,                          [DEFECT]
                       /resi_frot,                        [R]
```

By default the problem of Coulomb is solved by an algorithm of generalized Newton (`ALGO_RESO_FROT=' NEWTON'`), the only keyword which one can inform is thus `RESI_FROT` to define the criterion of stationnarity of the threshold (during `RESI_GEOM`, *cf.* 3.4.1). An additional column in the table of convergence makes it possible to follow the value of the criterion (column *CONTACT NEWTON GENE CRIT. FROT.*).

When one chooses `ALGO_RESO_FROT=' POINT_FIXE'`, the problem of Coulomb is solved by a succession of fixed points on the threshold of Tresca. To control this loop, the mechanism is the same one as on the loop of geometrical reactualization (*cf.* 3.4.1, `ITER_FROT_MAXI` play the part of `ITER_GEOM_MAXI` and `RESI_FROT` play the part of `RESI_GEOM`).

When one chooses `ADAPTATION=ADAPT_COEF`, one activates the possibility of controlling the coefficient of increase in friction (`COEF_ FROT`) by a method of treatment automatic of cyclings (see [R5.03.52]). This option is to be activated in the event of difficulties of convergence if one uses the method of generalized Newton, if a large number of cyclings occurs. The number of cyclings during an iteration is indicated in the column *CONTACT INFORMATION CYCLINGS* table of convergence.

3.4.4.4   Geometrical non-linearity

```
◊   RESI_GEOM      =   /0.000001,                        [DEFECT]
                       /resi_geom,                        [R]
```

The parameters of the fixed loop of point on the geometry (parameter by default) are given in the § 3.4.1 .

When one chooses `ALGO_RESO_ GEOM = ' NEWTON'`, one rocks towards the algorithm of generalized Newton. Geometrical non-linearity is then taken into account with each iteration of Newton: one remakes pairing and one recomputes the local base (normal and tangents). In this mode, a column additional appears in the table of convergence, it corresponds with the evaluation of the geometrical criterion (column *CONTACT NEWTON GENE CRIT. GEOM.*).
It is possible to modify the target value of this criterion, just like in the mode `POINT_FIXE` , using the parameter `RESI_GEOM` . However its definition in generalized Newton implies that it is generally checked before the criterion of balance of Newton . If one wants really to control it, it is thus necessary to rock in mode `POINT_FIXE` .

3.4.5   Formulation XFEM

3.4.5.1   Buckle of fixed point for the statutes of contact

```
◊   ITER_CONT_TYPE   =   /'MAXIMUM',                     [DEFECT]
                         /'MULT'
◊   ITER_CONT_MULT   =   /4,                             [DEFECT]
                         /iter_cont_mult,                [I]
◊   ITER_CONT_MAXI   =   /30,                            [DEFECT]
                         /iter_cont_maxi,                [I]
```

One can control the loop on the statutes of contact in two manners:
*   By giving the number **absolute** maximum of iterations of contact, `ITER_CONT_TYPE=' MAXI'` then `ITER_CONT_MAXI` ;
*   By giving the number **relative** maximum of iterations of contact by a multiplying coefficient, `ITER_CONT_TYPE=' MULT'` then `ITER_CONT_MULT` ; in this case, the iteration count on the statute of contact will be equal to the product `iter_cont_mult` by the number of nodes slaves.

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For the formulation XFEM, the statutes are changed per blocks and the maximum iteration count is thus more logically indicated in absolute value. In all the cases, the modification of these parameters is reserved for **experts** because it can lead to results **forgery** if friction is activated.

If one exceeds the maximum number of iterations of contact, one can then try to refine the grid, to subdivide the step of time or as a last resort to increase the value of ITER_CONT_MAXI/ITER_CONT_MULT.

3.4.5.2 Buckle of fixed point for friction

```
◊   ITER_FROT_MAXI   =   /10,                              [DEFECT]
                         /iter_frot_maxi,                  [I]
◊   RESI_FROT        =   /0.0001,                          [DEFECT]
                         /resi_frot,                       [R]
```

For the formulation XFEM (in small slips), the problem of Coulomb is solved by a succession of fixed points on the threshold of Tresca. To control this loop, the mechanism is the same one as on the loop of geometrical reactualization.

For X-FEM in great slips (REAC_GEOM! = ' SANS'), there is no loop on the thresholds of Tresca (algorithm of generalized Newton). The parameter ITER_FROT_MAXI no effect has then.

3.4.5.3 Management of the redundant edges

```
◊   ELIM_ARETE       =   /'DUAL',                          [DEFECT]
                         /'ELIM'
```

In the theoretical documentation of XFEM with taking into account of the contact/friction [R5.03.04], one explains the importance to eliminate certain edges cut by the level-set to observe the stability condition inf-sup (or condition LBB). This algorithm consists in establishing linear relations (equalities) between certain degrees of freedom. While activating ELIM_ARETE=' ELIM' , these relations are written in explicit form and the redundant degrees of freedom are eliminated from the unknown factors, which is more effective (less large model, less risk of problem of conditioning). In certain situations, this method can fail. In this case, it is enough to pass by again in mode ELIM_ARETE=' DUAL' .

3.4.6 Method without resolution

```
◊   STOP_INTERP      =   /'NOT',                           [DEFECT]
                         /'YES'
```

In the case of mode without resolution (see §3.5.4) the code emits an alarm as soon as it detects an interpenetration. The parameter STOP_INTERP allows to stop calculation instead of alarming the user.

3.5 Local parameters (zone by zone) of control of the resolution

3.5.1 Local parameters (zone by zone) of the formulation DISCRETE

```
♦   ZONE             =_F (local parameters)
```

The keywords of this paragraph are valid for the formulation DISCRETE. The parameters are defined by zone.

3.5.1.1 Method 'PENALIZATION'

```
♦   E_N              =   e_n                               [R]
♦   E_T              =   e_t                               [R]
```

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e_n is the coefficient of penalization on the interpenetration for the penalized method. It is homogeneous with the stiffness of springs placed between surfaces of contact to prevent the interpenetration. A value about the largest Young modulus of the solids in contact multiplied by a characteristic length is initially recommended. One will increase the value of the coefficient until obtaining stable results.

Moreover it is possible to control the distances from interpenetration and thus to refine its choice of coefficient, which is not the case in the presence of friction, since one does not know a priori which are the slipping zones and not slipping whereas in the event of contact one can check that the distances from interpenetration are small in front of dimensions characteristic of the zones of contact.

There exists in formulation DISCRETE an automatic adaptation mechanism of the coefficient of penalization E_N (*cf.* DEFI_LIST_INST [U4.34.03]).

e_t is the coefficient of penalization on the slip for the penalized method. It is necessary only when friction is active. It is necessary to increase the value of this coefficient until obtaining stable results.

3.5.1.2 Specific parameters for friction

```
♦   COULOMB        =   Coulomb                              [R]
◊   COEF_MATR_FROT =   coef_matr_frot                       [R]
```

The parameter COULOMB allows to regulate the coefficient of friction.
In the case of a penalized formulation, the parameter COEF_MATR_FROT, ranging between 0 and 1, allows to moderate the destabilizing effect of the negative part of the matrix of slip (which is added to tangent rigidity, *cf.* [R5.03.50]). More this coefficient is large, better is convergence when one is close to balance and more the resolution is difficult far from balance. A value of 0.5 is thus a good compromise. The value by default fixed at 0 ensures a better robustness for a longer computing time.

3.5.2 Local parameters (zone by zone) of the formulation CONTINUOUS

```
♦   ZONE           =_F (local parameters)
```

The keywords of this paragraph are valid for the formulation CONTINUOUS. The parameters are defined by zone.

3.5.2.1 Operands CONTACT_INIT/SEUIL_INIT

```
◊   CONTACT_INIT   =   /'INTERPENETRATES'                    [DEFECT]
                       /'YES'
                       /'NOT'
◊   SEUIL_INIT     =   /0.                                   [DEFECT]
                       /seuil_init                           [R]
```

Operands CONTACT_INIT and SEUIL_INIT allow respectively to fix the statute of contact at the initial state and the threshold of initial slip.

By defaults, only the connections with null game or interpenetrated are activated by the algorithm (CONTACT_INIT=' INTERPENETRE'). It is nevertheless possible to force the algorithm to activate all the connections without exception (CONTACT_INIT=' OUI'). The value CONTACT_INIT=' INTERPENETRE' is obligatory in the event of resumption of calculation with an initial state. It is also possible to disable any initial contact by CONTACT_INIT=' NON'.

As regards friction, the user can specify, if it wishes it, the value of the initial threshold (if it wishes an initial adherent contact for example). The threshold of slip has the dimension of a density of force surface. In a point of the surface of contact, there will be slip if the contact pressure λ and the coefficient of friction μ check: $\lambda \geq \mu \times SEUIL\_INIT$. The value which it will have chosen will apply to all the points of the zone of contact concerned. If no value is then indicated the behavior by default of SEUIL_INIT is such as:

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– if it is of a resumption of calculation or a calculation with initial state, then one automatically rebuilds the field of initial threshold of each point of contact by using the values of the component LAGS_C field DEPL specified in STAT_NON_LINE/ETAT_INIT,
– in the contrary case, the initial threshold is put at zero and all the points are potentially slipping.

3.5.2.2 Coefficients of the formulation CONTINUOUS

```
◊  ALGO_CONT      =  /'STANDARD'                    [DEFECT]
                      /'PENALIZATION'
{If ALGO_CONT == 'STANDARD'
     ♦   COEF_CONT =  /100.                          [DEFECT]
                      /coef_cont                     [R]
}
{If ALGO_CONT == 'PENALIZATION'
     ♦   COEF_PENA_CONT=coef_pena_cont               [R]
}


◊  ALGO_FROT      =  /'STANDARD'                    [DEFECT]
                      /'PENALIZATION'
{If ALGO_FROT == 'STANDARD'
     ♦   COEF_FROT =  /100.                          [DEFECT]
                      /coef_frot                     [R]
}
{If ALGO_FROT == 'PENALIZATION'
     ♦   COEF_PENA_ FROT= coef_pena_frot             [R]
}
```

The formulation continues is an increased Lagrangian formulation. There is a penalized version.
If one chooses ALGO_CONT=' STANDARD' and ALGO_FROT=' STANDARD', the formulation continues is then equivalent to a classical increased Lagrangian formulation whose coefficients of increase are given, respectively, by COEF_CONT and COEF_FROT.
If one chooses ALGO_CONT=' PENALISATION' and ALGO_FROT=' PENALISATION', the formulation then is purely penalized. One reaches only under the terms COEF_PENA_CONT and COEF_PENA_FROT.
The penalized method is described in the case of the discrete method with §3.4.3.5 and §3.5.1.1, COEF_PENA_CONT corresponds to it to E_N and COEF_PENA_FROT with E_T.
One can also to choose one mixed mode ALGO_CONT=' STANDARD' and ALGO_FROT=' PENALISATION'.

3.5.2.3 Operand ADAPTATION

```
◊  ADAPTATION          =         /'CYCLING'               [DEFECT]
                                  /'ADAPT_COEF'
                                  /'ALL'
                                  /'NOT'
```

The operand 'ADAPTATION' allows to select a method of treatment of the difficult case of convergence for the contact :
– 'NOT' there is no treatment ;
– 'ADAPT_COEF' one plays only on COEF_PENA_CONT, COEF_PENA_FROT in contact with or without friction in mode ALGO_CONT penalized and on COEF_FROT in mode ALGO_CONT standard ;
– 'CYCLING' : the frequent changes of statutes of contact influence the calculation of the matrices of contact. ON plays only on the calculation of the matrices of contact and friction for better controlling the changes of status. The calculation of matrix of contact is a convex combination enters matrices state (pressure, game, statute) of the point of contact cycling with the preceding iteration and the current iteration ;
– ' ALL ' : the mode is combined 'CYCLING' with the mode 'ADAPT_COEF'.

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3.5.2.4 Operand INTEGRATION

```
◊   INTEGRATION    =  /'CAR'                              [DEFECT]
                      /'GAUSS'
                      /'SIMPSON'
                      /'NCOTES'

{If INTEGRATION ==  'GAUSS'
     ◊   ORDRE_INT   =  /3                                [DEFECT]
                        /1≤ordre_int ≤6                   [I]
}
{If INTEGRATION ==  'SIMPSON'
     ◊   ORDRE_INT   =  /1                                [DEFECT]
                        /1≤ordre_int ≤4                   [I]
}
{If INTEGRATION ==  'NCOTES'
     ◊   ORDRE_INT   =  /3                                [DEFECT]
                        /3≤ordre_int ≤8                   [I]
}
```

The operand 'INTEGRATION' allows to select a method of integration digital for the terms of contact and friction. Several methods are implemented:

– 'CAR' to let the code choose the diagram of integration more adapted (of standard trapezoid or Simpson);
– 'GAUSS' for a squaring of Gauss with the possibility of choosing the degree of the polynomials which the diagram makes it possible to integrate exactly;
– 'SIMPSON' for a diagram of Simpson ($1/3$) with the possibility of choosing the number of subdivisions of the element of reference;
– 'NCOTES' for a diagram of Newton-Dimensions with the possibility of choosing the degree of the polynomials interpolaters.

The choice of the degree of the polynomials which one integrates exactly or amongst subdivisions for the diagram of Simpson is done with the keyword ORDRE_INT.

Automatic integration (by default choice) is most general and most effective. The choice of a diagram of integration is to be held for **experts**.

3.5.2.5 Operand SLIDE

```
◊   SLIDE         =  /'NOT'                               [DEFECT]
                     /'YES'
```

Contrary to the discrete formulation (see §3.4.3.3), it is possible to activate this option zones by zone.

3.5.3 Local parameters (zone by zone) of the formulation XFEM

```
♦   ZONE            =  _F (local parameters)
```

The keywords of this paragraph are valid for the formulation XFEM . The parameters are defined by zone.

3.5.3.1 Operand FISS_MAIT

```
♦   FISS_MAIT      =  fiss_mait                           [fiss_xfem]
```

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For the formulation XFEM , the user provides the crack whose lips potentially will make contact (FISS_MAIT). The expected concept is resulting from the operator DEFI_FISS_XFEM [U4.82.08].

3.5.3.2 Operands CONTACT_INIT/SEUIL_INIT

```
◊   CONTACT_INIT    =   /'NOT'                           [DEFECT]
                        /'YES'
◊   SEUIL_INIT      =   /0.                              [DEFECT]
                        /seuil_init                      [R]
```

Cf. 3.5.2.1.

3.5.3.3 Coefficients of the formulation XFEM

```
◊   ALGO_CONT       =   /'STANDARD'                      [DEFECT]
                        /'PENALIZATION'
                        /'CZM'
◊   COEF_CONT       =   /100.                            [DEFECT]
                        /coef_cont                       [R]
◊   COEF_PENA_CONT  =   /100.                            [DEFECT]
                        /coef_pena_cont                  [R]
◊   ALGO_FROT       =   /'STANDARD'                      [DEFECT]
                        /'PENALIZATION'
◊   COEF_FROT       =   /100.                            [DEFECT]
                        /coef_frot                       [R]
◊   COEF_PENA_FROT  =   /100.                            [DEFECT]
                        /coef_pena_frot                  [R]
```

The formulation XFEM is writing of a continuous type. The choice of the coefficients is the same one as in the case of the formulation (§ continues3.5.2.2).

The algorithm ALGO_CONT = 'CZM' (Cohesive Model Zone) is particular. It is used when one wishes to model cohesive forces between two lips of a crack. The contact is then taken into account by a term of penalization in the law cohesive. The parameters relating to the law of contact-friction should not then be indicated. Indeed, the parameter COEF_PENA_CONT is for example useless, the coefficient of penalization being given starting from the parameters materials provided in the operator DEFI_MATERIAU [U4.43.01], under the keyword RUPT_FRAG. The tangential constraint obeying the cohesive law and not a law of friction, no keyword relating to friction is used.

3.5.3.4 Operand INTEGRATION

```
◊   INTEGRATION       =   /'NODE'                        [DEFECT]
                          /'GAUSS'
                          /'SIMPSON'
                          /'NCOTES'


{If INTEGRATION ==   'GAUSS'
      ◊   ORDRE_INT   =   /6                             [DEFECT]
                          /1≤ordre_int ≤6                [I]
}
{If INTEGRATION ==   'SIMPSON'
      ◊   ORDRE_INT   =   /1                             [DEFECT]
                          /1≤ordre_int ≤4                [I]
}
{If INTEGRATION ==   'NCOTES'
      ◊   ORDRE_INT   =   /3                             [DEFECT]
                          /3≤ordre_int ≤8                [I]
}
```

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This keyword has the same meaning as that of the formulation CONTINUOUS, *cf.* §3.5.2.4. It is a parameter to be held for **experts**.

3.5.3.5 Operand SLIDE

◊ SLIDE = /'NOT' [DEFECT]
/'YES'

Contrary to the discrete formulation (see § 3.4.3.3), it is possible to activate this option zones by zone.

3.5.3.6 Operand ALGO_LAGR

◊ ALGO_LAGR = /'CAR' [DEFECT]
/'VERSION1'
/'VERSION2'
/'VERSION3'
/'NOT'

This keyword determines the choice of the algorithm of elimination of Lagrange of friction to satisfy condition LBB (see [R7.02.12]). This parameter is of a use intended for **experts**. When the keyword 'CAR' is activated, for quadratic elements with REAC_GEOM == 'WITHOUT', one rocks on ALGO_LAGR == 'VERSION3'. In all the other cases, one activates ALGO_LAGR ==' VERSION2'.

3.5.3.7 Operand RELATION

◊ RELATION = /'CZM_EXP_REG' [DEFECT]
/'CZM_LIN_REG'
/'CZM_TAC_MIX'
/'CZM_OUV_MIX'
/'CZM_LIN_MIX'

The keyword RELATION allows to activate the taking into account of forces of cohesion at the time of the opening of an interface X-FEM. It is used exclusively with the option ALGO_CONT = 'CZM'. Cohesion is modelled by the cohesive law of the same name, already existing of finite element method classical (see the note of use [U2.05.07] for a summary, documentation [R7.02.11] for the definition of these laws and documentation [R5.03.54] for their extension to X-FEM). At present, the only law being able to be used for studies of propagation on unknown way is CZM_LIN_MIX, a mixed law (perfect initial adherence) used with linear elements.
The data necessary of the field material are provided in the operator DEFI_MATERIAU [U4.43.01], under the keyword RUPT_FRAG.

3.5.4 Method without resolution

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

◊ TOLE_INTERP = /0. , [DEFECT]
/tole_interp [R]

When RESOLUTION=' NON', one carries out a control of the interpenetration of two surfaces without imposing the conditions of contact (if there is interpenetration, it will not be corrected).
The code emits an alarm as soon as an interpenetration is detected at the end of a step of loading. The total parameter STOP_INTERP (§3.4.6) allows to stop calculation instead of alarming the user.

TOLE_INTERP (zone by zone) rule the value of tolerated interpenetration (homogeneous with a length in the unit of the grid). The value given is absolute (does not have sign). This method is available in discrete and continuous formulation.

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Remarks :

- *In mode* RESOLUTION=' NON'*, pairing is made only once at the end of each step of time, the concept of loop geometrical does not exist any more if all the zones are in mode* RESOLUTION=' NON'*. In this last case, the option* REAC_GEOM *if it is different from* 'WITHOUT' *thus does not have direction.*
- *The fact that mode* RESOLUTION=' NON' *detect interpenetrations in one of the zones of contact does not prejudge only it real calculation (with effective checking of the unilateral condition) gives the same results. Indeed, the activation of the unilateral condition necessarily will change the kinematics of deformation compared to the mode* RESOLUTION=' NON'*. It is thus advisable to be careful when one mixes zones with resolution of the contact and others without resolution.*
- *The nodes interpenetrated in this mode have the statute* CONT=3 *in field* CONT_NOEU?

3.6   Field CONT_NOEU

To facilitate postprocessing, the field CONT_NOEU is produced systematically with resulting from a calculation with contact and it is available in the structure of data result (of type evol_noli). It contains the following components defined in each node slave:

- CONT : indicator of rubbing contact
    - −1 : the node (or the point of integration) is not paired (for example out of the mesh Master, to see TOLE_PROJ_EXT)
    - 0 : no the contact
    - 1 : adherent contact (only if FROTTEMENT=' COULOMB')
    - 2 : slipping contact
    - 3 : if there is interpenetration (only in mode RESOLUTION=' NON');
- GAME : value of the game
- RN : normal reaction of contact normalizes
- RNX : component according to DX normal reaction of contact
- RNY : component according to DY normal reaction of contact
- RNZ : component according to DZ normal reaction of contact
- GLIX : component according to t_1 tangential slip (local reference mark)
- GLIY : component according to t_2 tangential slip (local reference mark)
- GLI : normalizes tangential slip
- RTAX : component according to DX tangential force of adherence
- RTAY : component according to DY tangential force of adherence
- RTAZ : component according to DZ tangential force of adherence
- RTGX : component according to DX tangential force of slip
- RTGY : component according to DY tangential force of slip
- RTGZ : component according to DZ tangential force of slip
- X-ray : component according to DX force of rubbing contact (RNX+RTAX+RTGX)
- RY : component according to DY force of rubbing contact (RNY+RTAY+RTGY)
- RZ : component according to DZ force of rubbing contact (RNZ+RTAZ+RTGZ)
- R : force of rubbing contact normalizes
- I : percussion of the resultant R force of rubbing contact
- IX : percussion of the component according to DX force of rubbing contact
- IY : percussion of the component according to DY force of rubbing contact
- IZ : percussion of the component according to DZ force of rubbing contact
- PT_X : coordinates according to DX point of intersection in formulation XFEM
- PT_Y : coordinates according to DY point of intersection in formulation XFEM
- PT_Z : coordinates according to DZ point of intersection in formulation XFEM

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- PROJ_X : coordinates according to DX projection of the node slave on the mesh or the main node
- PROJ_Y : coordinates according to DY projection of the node slave on the mesh or the main node
- PROJ_Z : coordinates according to DZ projection of the node slave on the mesh or the main node

Remarks :

- *in formulation 'CONTINUES' , this field is produced only with the diagram of integration by default (cf § 3.5.2.4);*
- *in formulation ' XFEM' , the component CONT is not stored.*

It is printed as follows in the form of table:

```
MATABLE=POST_RELEVE_T (ACTION=_F (INTITULE=' INFORMATION FROTTEMENT',
                       GROUP_NO=' ESCLAVE',
                       RESULTAT=U,
                       INST=10.,
                       TOUT_CMP=' OUI',
                       NOM_CHAM=' CONT_NOEU',
                       OPERATION=' EXTRACTION',),);


IMPR_TABLE (TABLE=MATABLE);
```

It is advisable to notice that the quantities corresponding to the reactions of contact-friction are nodal efforts (in unit of force) within the meaning of the finite elements and not of contact pressures. In axisymmetric modeling, just like for the option FORC_NODA or REAC_NODA, it is thus necessary to multiply the values obtained by 2π to obtain the resultant (*cf.* [U4.81.02]). The nodal forces punctually do not have a direction (they depend on the smoothness of the grid), only their resultant can be interpreted.

More generally, to have access to contact pressures, one will refer to the note of use of the contact [U2.04.04] which describes the manners of recovering them when they are produced by calculation or to rebuild them in the contrary case.

3.7 Field CONT_ELEM

For postprocessing method LAKE, the field CONT_ELEM is produced systematically with resulting from a calculation with contact and it is available in the structure of data result (of type evol_noli). It contains the following components defined in each mesh slave:

- X1 : value of the contact pressure
- X2 : value of the integrated game (it is negative if the node is not paired, positive or null in the contrary case)
- X3 : indicator of contact
    - −1 : mesh is not pairedE
    - 0 : no the contact
    - 1 : contact
- X4 : surface of intersection. This value understood enters 0 and 1 indicate the portion of the mesh slave which is actually intersected by the meshs Masters
- X5 : product of X4 and of X1

3.8 Formulation LIAISON_UNIL

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The formulation `LIAISON_UNIL` is usable to define a unilateral condition (inequation) of nodal type on unspecified degrees of freedom such as:

$$\sum \alpha_i(t)\, p_i < r(x, y, z, t)$$

with:

– p_i the value of the degree of freedom of a node (displacement, pressure, temperature, etc…) (§3.8.1.3)
– $\alpha_i(t)$ a real function of time (parameter `INST`) (§3.8.1.4)
– $r(x, y, z, t)$ a real function of time or space (parameters X, Y, Z, INST) (§3.8.1.4)

It will be noticed that the parameter α_i also allows, if its sign is negative, to reverse the direction of the inequality.

3.8.1 Local parameters (zone by zone) of the formulation `LIAISON_UNIL`

♦   ZONE   = _F (*local parameters*)

The keywords of this paragraph are valid for the formulation `LIAISON_UNIL`. The parameters are defined by zone.

3.8.1.1 Operands `GROUP_MA/GROUP_NO`

♦ /GROUP_NO   =   l_grno   [l_gr_noeud]
   /GROUP_MA   =   l_grma   [l_gr_maille]

The unilateral condition is expressed on the nodes of the grid given under the keyword `GROUP_NO`. One can nevertheless give the meshs carrying the nodes thanks to the keyword `GROUP_MA`. Contrary to the case of the "classical" contact, as the conditions are nodal, it is useless to direct the normals with the meshs of skin in the case `LIAISON_UNIL`.

3.8.1.2 Operands `SANS_GROUP_NO`

◊   SANS_GROUP_NO   = l_sgrno   [l_gr_noeud]

Ittte operand makes it possible to exclude from the nodes of the unilateral condition in the same way as for the formulations `CONTINUOUS` or `DISCRETE` (see §3.1.3).

3.8.1.3 Operand `NOM_CMP`

♦   NOM_CMP   =   l_cmp   [l_TXM]

List of the components p_i (degrees of freedom) on which is exerted the unilateral relation. It can be any degree of freedom carried by the node. For example: PRE, PRE1, PRE2, TEMP or DX, DY or DZ.

3.8.1.4 Operands `COEF_IMPO` and `COEF_MULT`

♦   COEF_IMPO   =   l_c_impo   [function]
♦   COEF_MULT   =   l_c_mult   [l_fonction]

`COEF_IMPO` is the value $r(t)$ imposed to the member of right-hand side of the unilateral relation. `COEF_MULT` is the list of the multiplying coefficients $\alpha(t)$ used in front of each degree of freedom. Lengths of the lists `COEF_MULT` and `NOM_CMP` must of course be identical.
Coefficients $r(t)$ and $\alpha(t)$ are inevitably **functions**. To define constant coefficients, it will be advisable to use the order `DEFI_CONSTANTE`.

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3.8.2 Example

One wants to impose the condition `1.3*PRE1-5.2*PRE2 < 4.0`, one will have then:

```
coef_i  = DEFI_CONSTANTE (VALE=4.0)
coef_m1 = DEFI_CONSTANTE (VALE=1.3)
coef_m2 = DEFI_CONSTANTE (VALE=-5.2)

NOM_CMP = ('PRE1', 'PRE2')
COEF_IMPO = coef_i
COEF_MULT = (coef_m1, coef_m2)
```