Operator DEFI_CONTACT

1 Abstract

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

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2 Syntax

```
char_contact = DEFI_CONTACT
(
♦  MODELE          =  Mo,                                  [model]
◊  INFO            =  /1,                                  [DEFAUT]
                      /2,

♦  FORMULATION     =  /'DISCRETE»                          [DEFAUT]
                      /'CONTINUE»
                      /'XFEM»
                      /'LIAISON _UNIL»

# For the contact-friction formulation
{If FORMULATION   ! = «LIAISON_UNIL»
   ◊  FROTTEMENT   =  /'SANS»,                             [DEFAUT]
                      /'COULOMB»,

# General parameters for the meshed contact
{If FORMULATION   = =«DISCRETE» or FORMULATION  = =«CONTINUE»}
   ◊  STOP_INTERP     =  /'NON»,                           [DEFAUT]
                         /'OUI»
   ◊  LISSAGE         =  /'NON»,                           [DEFAUT]
                         /'OUI»,
   ◊  VERI_NORM       =  /'OUI»,                           [DEFAUT]
                         /'NON»,
}

# General Parameters for XFEM contact
{If FORMULATION   = =«XFEM»}
   ◊  ELIM_ARETE      =  /'DUAL»,                          [DEFAUT]
                         /'ELIM»
}

# Control the geometrical non-linearity
{If FORMULATION = = «CONTINUE»
   ◊  ALGORITHME_RESO_GEOM   =  /'POINT _FIXE»,
   [DEFAUT]
                         /«NEWTON',
}
{If FORMULATION = = «DISCRETE» or (FORMULATION = = «CONTINUE» and
ALGORITHME_RESO_GEOM = =' POINT_FIXE ')
   ◊  REAC_GEOM       =  /'AUTOMATIQUE»,                   [DEFAUT]
                         /«CONTROLE»,
                         /«SANS»
   {If REAC_GEOM = =   «AUTOMATIQUE»
      ◊  ITER_GEOM_MAXI   =  /10,                          [DEFAUT]
                             /iter_geom_maxi,              [I]
      ◊  RESI_GEOM        =  /0.01,                        [DEFAUT]
                             /resi_geom,                   [R]
   }
   {If REAC_GEOM = =   «CONTROLE»
      ◊  NB_ITER_GEOM     =  /2,                           [DEFAUT]
                             /nb_iter_geom,                [I]
    }
}
{ If (FORMULATION = = «CONTINUE» and ALGORITHME_RESO_GEOM = = «NEWTON»)
```

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```
    ◊  RESI_GEOM        =  /0.000001,                          [DEFAUT]
                           /resi_geom,                         [R]
}
{If FORMULATION = = «XFEM»
    ◊  REAC_GEOM        =  /«SANS',                            [DEFAUT]
                           /'AUTOMATIQUE»,
                           /'CONTRÔLE»,
    {If REAC_GEOM = = «AUTOMATIQUE»
       ◊  ITER_GEOM_MAXI   =  /10,                             [DEFAUT]
                              /iter_geom_maxi,                 [I]
       ◊  RESI_GEOM        =  /0.0001,                         [DEFAUT]
                              /resi_geom,                      [R]
    }
    {If REAC_GEOM = = «CONTROLE»
       ◊  NB_ITER_GEOM     =  /2,                              [DEFAUT]
                              /nb_iter_geom,                   [I]
    }
}
```

Control the non-linearity of contact

```
{If FORMULATION = = «DISCRETE»
    ◊  ITER_CONT_MULT   =  /4,                                 [DEFAUT]
                           /iter_cont_mult,                    [I]
}
{If FORMULATION = = «CONTINUE» or FORMULATION = = «XFEM»
    {If FORMULATION = = «CONTINUE»
       ◊  ALGORITHME_RESO_CONT   =  /'NEWTON»,
    [DEFAUT]
                              /«POINT_FIXE',
    }
    {If (FORMULATION = = «CONTINUE» and ALGORITHME_RESO_CONT = =' POINT_FIXE ')
or FORMULATION = = «XFEM»
       ◊  ITER_CONT_TYPE   =  /'MAXI»,                         [DEFAUT]
                              /'MULT»

       {If ITER_CONT_TYPE   = = «MULT»
          ◊  ITER_CONT_MULT   =  /4,                           [DEFAUT]
                                 /iter_cont_mult,              [I]
       }
       {If ITER_CONT_TYPE   = = «MAXI»
          ◊  ITER_CONT_MAXI   =  /30,                          [DEFAUT]
                                 /iter_cont_maxi,              [I]
       }
    }
}
```

Control the non-linearity of friction threshold

```
{ If FROTTEMENT = =  «COULOMB»
    {If FORMULATION   = = «CONTINUE»
       ◊  ALGORITHME_RESO_FROT   =  /'NEWTON»,
    [DEFAUT]
                              /«POINT_FIXE',
    }
    {If (FORMULATION = = «CONTINUE» and ALGORITHME_RESO_FROT = =' POINT_FIXE ')
or FORMULATION = = «XFEM»
       ◊  ITER_FROT_MAXI   =  /10,                             [DEFAUT]
                              /iter_frot_maxi,                 [I]
       ◊  RESI_FROT        =  /0.0001,                         [DEFAUT]
```

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```
                                /resi_frot,                        [R]
    }
    {If (FORMULATION = = «CONTINUE» and ALGORITHME_RESO_FROT   = =»NEWTON')
       ◊  RESI_FROT        =  /0.0001,                             [DEFAUT]
                               /resi_frot,                         [R]
       ◊  ADAPT_COEF       =  /'NON»                               [DEFAUT]
                               /'OUI»
    }

}

# General parameters of discrete formulations
{If FORMULATION   = =«DISCRETE»
    # dualized Methods (CONTRAINTE)
    ◊  STOP_SINGULIER   =  /'OUI»,                                 [DEFAUT]
                           /'NON»
    ◊  NB_RESOL         =  /10,                                    [DEFAUT]
                           /nb_resol                               [I]

    # Method «GCP»
    ◊  RESI_ABSO        =  /resi_abso                              [R]
    ◊  ITER_GCP_MAXI    =  /0,                                     [DEFAUT]
                           /iter_gcp_maxi
    ◊  RECH_LINEAIRE    =  /'ADMISSIBLE»,                          [DEFAUT]
                           /'NON _ADMISSIBLE»
    ◊  PRE_COND         =  /'SANS»,                                [DEFAUT]
                           /'DIRICHLET»
    {If PRE_COND = = «DIRICHLET»
       ◊  ITER_PRE_MAXI    =  /0,                                  [DEFAUT]
                              /iter_pre_maxi
       ◊  COEF_RESI        =  /-1. ,                               [DEFAUT]
                              /coef_resi                           [R]
    }
}

# Assignment of the case DISCRET
{If FORMULATION   = =«DISCRETE»
    ZONE = _f (
       ♦  /MAILLE_MAIT     =  l_maille_mait                        [l_maille]
          /GROUP_MA_MAIT   =  grma_mait                            [] gr_maille
       ♦  /MAILLE_ESCL     =  l_maille_escl                        [l_maille]
          /GROUP_MA_ESCL   =  grma_escl                            [] gr_maille

       ◊  SANS_NOEUD       =  l_snoeud                             [] l_noeud
       ◊  SANS_GROUP_NO    =  l_sgrno                              [] l_gr_noeud
       ◊  SANS_MAILLE      =  l_smaille                            [l_maille]
       ◊  SANS_GROUP_MA    =  l_sgrma                              []
l_gr_maille

       ◊  APPARIEMENT      =  /'MAIT _ESCL»                        [DEFAUT]
                              /'NODAL»

       ◊  NORMALE          =  /'MAIT»                              [DEFAUT]
                              /'MAIT _ESCL»
                              /'ESCL»

       ◊  VECT_MAIT        =  /'AUTO»                              [DEFAUT]
                              /'FIXE»
                              /'VECT _y»
```

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```
{If VECT_MAIT = =' FIXE '
   ♦  MAIT_FIXE    =  (Yx, Yy, Yz)                    [R]
}
{If VECT_MAIT = = «VECT_Y»
   ♦  MAIT_VECT_Y  =  (Yx, Yy, Yz)                    [R]
}

◊  VECT_ESCL =  /'AUTO»                               [DEFAUT]
                /'FIXE»
                /'VECT _y»
{If VECT_ESCL = =' FIXE '
   ♦  ESCL_FIXE    =  (Yx, Yy, Yz)                    [R]
}
{If VECT_ESCL = = «VECT_Y»
   ♦  ESCL_VECT_Y  =  (Yx, Yy, Yz)                    [R]
}

◊  TYPE_APPA       =  /'PROCHE»                       [DEFAUT]
                      /'FIXE»
{ If TYPE_APPA= =' FIXE '
   ♦  DIRE_APPA    =  (Yx, Yy, Yz)                    [R]
}

◊  DIST_POUTRE     =  /'NON»                          [DEFAUT]
                      /'OUI»
◊  DIST_COQUE      =  /'NON»                          [DEFAUT]
                      /'OUI»
{If DIST_POUTRE = =  ' OUI» or DIST_COQUE = =   ' OUI»
   ♦  CARA_ELEM =  carac                              [cara_elem]
}

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

◊  TOLE_APPA       =  /-1.0                           [DEFAUT]
                      /tole_appa                      [R]
◊  TOLE_PROJ_EXT   =  /0.50                           [DEFAUT]
                      /tole_proj_ext                  [R]

# Deactivation of the resolution
◊  RESOLUTION      =  /'OUI»                          [DEFAUT]
                      /'NON»
{If RESOLUTION = = «NON»
      ◊  TOLE_INTERP     =  /0. ,                     [DEFAUT]
                            /tole_interp              [R]
}

♦  ALGORITHME_CONT        =  /'CONTRAINTE»
[DEFAUT]
                      /'GCP»
                      /'PENALISATION»

{If ALGORITHME_CONT = = «CONTRAINTE»
   ◊  GLISSIERE       =  /'NON»                      [DEFAUT]
                         /'OUI»
   {If GLISSIERE = = ' OUI»
      ◊  ALARME_JEU   =  /0                           [DEFAUT]
                         /alarme_jeu                  [R]
   }
```


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```
            }

            {If ALGORITHME_CONT = = «PENALIZATION»
               ♦  E_N              =  e_n                          [R]
            }

            {If FROTTEMENT = =   «COULOMB»
               ♦  COULOMB          =  Coulomb                      [R]
               ◊  COEF_MATR_FROT   =  /0.                          [R]
                                      /coef_matr_frot
                ♦ ALGORITHME_FROT        =  /'PENALISATION»
[DEFAUT]
               {If ALGO_FROT = =   «PENALIZATION»
                  ♦  E_T       =  e_t                             [R]
               }
            }
      }
```

Assignment of the case CONTINU

```
      {If FORMULATION   = =«CONTINUE»
         ZONE = _f (
            ♦  /MAILLE_MAIT     =  l_maille_mait                  [l_maille]
               /GROUP_MA_MAIT   =  grma_mait                      [] gr_maille
            ♦  /MAILLE_ESCL     =  l_maille_escl                  [l_maille]
               /GROUP_MA_ESCL   =  grma_escl                      [] gr_maille

            ◊  SANS_NOEUD       =  l_snoeud                       [] l_noeud
            ◊  SANS_GROUP_NO    =  l_sgrno                        [] l_gr_noeud
            ◊  SANS_MAILLE      =  l_smaille                      [l_maille]
            ◊  SANS_GROUP_MA    =  l_sgrma                        []
      l_gr_maille

            ◊  APPARIEMENT      =  /'MAIT _ESCL»                  [DEFAUT]

            ◊  NORMALE          =  /'MAIT»                        [DEFAUT]
                                   /'MAIT _ESCL»
                                   /'ESCL»

            ◊  VECT_MAIT        =  /'AUTO»                        [DEFAUT]
                                   /'FIXE»
                                   /'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 =  /'AUTO»                               [DEFAUT]
                            /'FIXE»
                            /'VECT _y»
            {If VECT_ESCL = =' FIXE '
               ♦  ESCL_FIXE     =  (Yx, Yy, Yz)                   [R]
            }
            {If VECT_ESCL = = «VECT_Y»
               ♦  ESCL_VECT_Y   =  (Yx, Yy, Yz)                   [R]
            }

            ◊  TYPE_APPA        =  /'PROCHE»                      [DEFAUT]
```

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```
                                /'FIXE»
            {If TYPE_APPA = =' FIXE '
               ♦  DIRE_APPA     =  (Yx, Yy, Yz)                    [R]
            }

            ◊  DIST_POUTRE      =  /'NON»                          [DEFAUT]
                                   /'OUI»
            ◊  DIST_COQUE       =  /'NON»                          [DEFAUT]
                                   /'OUI»
            {If DIST_POUTRE = =  ' OUI» or DIST_COQUE = =   ' OUI»
               ♦  CARA_ELEM =  carac                               [cara_elem]
            }

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

            ◊  TOLE_APPA        =  /-1.0                           [DEFAUT]
                                   /tole_appa                      [R]
            ◊  TOLE_PROJ_EXT    =  /0.50                           [DEFAUT]
                                   /tole_proj_ext                  [R]

            # Deactivation of the resolution
            ◊  RESOLUTION       =  /'OUI»                          [DEFAUT]
                                   /'NON»
            {If RESOLUTION = =   ' NON»
                ◊  TOLE_INTERP      =  /0. ,                       [DEFAUT]
                                       /tole_interp               [R]
            }

            ◊  GLISSIERE        =  /'NON»                          [DEFAUT]
                                   /'OUI»
            ◊  CONTACT_INIT     =  /'INTERPENETRE»                 [DEFAUT]
                                   /'OUI»
                                   /'NON»

            ◊  INTEGRATION      =  /'AUTO»                         [DEFAUT]
                                   /'GAUSS»
                                   /'SIMPSON»
                                   /'NCOTES»

            {If INTEGRATION = =  «GAUSS»
               ◊  ORDRE_INT     =  /3                              [DEFAUT]
                                   /1≤ordre_int ≤ 6                [I]
            }
            {If INTEGRATION = =  «SIMPSON»
               ◊  ORDRE_INT     =  /1                              [DEFAUT]
                                   /1≤ordre_int ≤ 4                [I]
            }
            {If INTEGRATION = =  «NCOTES»
               ◊  ORDRE_INT     =  /3                              [DEFAUT]
                                   /3≤ordre_int ≤ 8                [I]
            }
            ◊  ALGORITHME_CONT        =  /'STANDARD»
[DEFAUT]
                                   /'PENALISATION»

            {If ALGORITHME_CONT = = «STANDARD»
               ◊  COEF_CONT     =  /100.                           [DEFAUT]
                                   /coef_cont                      [R]
```

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```
            }
            {If ALGORITHME_CONT = = «PENALIZATION»
               ♦  COEF_PENA_CONT = coef_pena_cont                    [R]
            }

            {If FROTTEMENT = = «COULOMB»
               ♦  COULOMB          =  Coulomb                        [R]
               ◊  /SANS_NOEUD_FR      =  l_sfnoeud                   [] l_noeud
                  /SANS_GROUP_NO_FR   =  l_sgrno                     [] l_gr_noeud
               {If SANS_NOEUD_FR! = None or SANS_GROUP_NO_FR! = None
                  ◊  DIRE_EXCL_FROT      =  (Yx, Yy, Yz)             [R]
               }

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

               ◊  ALGORITHME_FROT        =  /'STANDARD»
[DEFAUT]
                                     /'PENALISATION»

               {If ALGORITHME_FROT = = «STANDARD»
                  ◊  COEF_FROT    =  /100.                          [DEFAUT]
                                     /coef_frot                     [R]
               }
               {If ALGORITHME_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      =  /'NOEUD»
                                   /'GAUSS»                         [DEFAUT]
                                   /'SIMPSON»
                                   /'NCOTES»
            {If INTEGRATION = =  «GAUSS»
               ◊  ORDRE_INT     =  /6                               [DEFAUT]
                                   /1≤ordre_int ≤ 6                 [I]
            }
            {If INTEGRATION = =  «SIMPSON»
               ◊  ORDRE_INT     =  /1                               [DEFAUT]
                                   /1≤ordre_int≤ 4                  [I]
            }
            {If INTEGRATION = =  «NCOTES»
               ◊  ORDRE_INT     =  /3                               [DEFAUT]
                                   /3≤ordre_int ≤ 8                 [I]
            }
            ◊  CONTACT_INIT     =  /'NON»                          [DEFAUT]
                                   /'OUI»
            ◊  ALGORITHME_LAGR        =  /'AUTO»
[DEFAUT]
                                   /'VERSION 1»
                                   /'VERSION 2»
                                   /'VERSION 3»
                                   /'NON»
            ◊  TOLE_PROJ_EXT    =  /0.50                            [DEFAUT]
```

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```
                                    /tole_proj_ext                    [R]
          ◊  ALGORITHME_CONT          =  /'STANDARD»
[DEFAUT]
                                    /'PENALISATION»
                                    /'CZM»

          {If ALGORITHME_CONT = = «STANDARD»
             ◊  COEF_CONT     =  /100.                              [DEFAUT]
                                    /coef_cont                        [R]
          }
          {If ALGORITHME_CONT = = «PENALIZATION»
             ♦  COEF_PENA_CONT   =  /coef_pena_cont                 [R]
          }
          { If ALGORITHME_CONT = =«CZM»
             ♦  RELATION         =  /'CZM _EXP_REG»                 [DEFAUT]
                                    /'CZM _LIN_REG»
                                    /'CZM _OUV_MIX»
                                    /'CZM _TAC_MIX»
                                    /'CZM _LIN_MIX»
          }

          ◊  GLISSIERE        =  /'NON»                             [DEFAUT]
                                    /'OUI»

          {If = = «COULOMB»
             ♦  COULOMB          =  Coulomb                         [R]
             ◊  SEUIL_INIT       =  /0.                             [DEFAUT]
                                    /seuil_init                     [R]
             ◊  ALGORITHME_FROT        =  /'STANDARD»
[DEFAUT]
                                    /'PENALISATION»

             {If ALGORITHME_FROT = = «STANDARD»
                ◊      COEF_FROT    =  /100.                        [DEFAUT]
                                       /coef_frot                   [R]
             }
             {If ALGORITHME_FROT = = «PENALIZATION»
                ♦      COEF_PENA_FROT  =  /coef_pena_frot          [R]
             }
          }
    }

    # Assignment of the case LIAISON_UNIL
    {If FORMULATION   = =«LIAISON_UNIL»
       ZONE = _f (
          ♦  /NOEUD           =  l_noeud                            [] l_noeud
             /GROUP_NO        =  l_grno                             [] l_gr_noeud
             /MAILLE          =  l_maille                           [l_maille]
             /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_NOEUD        =  l_snoeud                           [] l_noeud
          ◊ SANS_GROUP_NO     =  l_sgrno                            [] l_gr_noeud
       )
    }
);
```

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3 Principles

This command makes it possible to describe the areas subjected to unilateral contact with or without friction. Description is divided into two levels:

- Global parameters like the choice of the formulation or the parameters of control of the nonlinear algorithm (fixed-point or Newton, specific parameters for the solver);
- Local parameters specific to each contact zone.

The concept resulting from DEFI_CONTACT is then well informed as parameter in the simple keyword CONTACT operators STAT_NON_LINE [U 4.51.03] and DYNA_NON_LINE [U 4.53.01]. Each zone contains two surfaces being able to make contact are described by the mesh groups which constitute them.
The groups of meshes potentially in contact is skin meshes: surface and linear in dimension 3 (QUAD9, QUAD8, QUAD4, TRIA7, TRIA6, TRIA3, SEG3, SEG2), linear and punctual 2 (SEG3, SEG2 and POI1).
In dimension 2, the mesh of the type POI1 must compulsorily be on the slave surface. They are not usable with the formulation CONTINUE.
In dimension 3, the mesh of the type SEG2 or SEG3 must compulsorily be on the slave surface. 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, processing of the contact with quadratic edge meshes type QUAD8 require to connect the middles nodes to the tops nodes in order to have correct results. This operation is carried out automatically in the code. Nevertheless, for computations 3d continuous media the use of elements HEXA27 or PENTA18 (with sides 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 vertexes of the meshes 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 CONTINUE, in dimension 3, the use of quadratic edge meshes type QUAD8 or TRIA6 curves (i.e. the middles nodes are not aligned with the tops nodes) can involve violations of contact law. More precisely the contact is then solved on average on each element. In the presence of contact one can observed clearances at the same time slightly positive and negative what can disturb the results close to the contact zone or recovery computations with initial state. For this reason it is **advised** to use elements HEXA27 or PENTA18 (with sides QUAD9) or many linear elements.*
> – *One can transform into HEXA27 or PENTA18 a mesh made up of elements HEXA20 or PENTA15 using the operator CREA_MAILLAGE [U 4.23.02].*

The studied structures may undergo large sliding one compared to the other. There are four types of formulations:

1) Discrete formulations (see [R 5.03.50]) which correspond with the resolution of the discretized unilateral problem (displacements and nodal forces unknown). This formulation is performed *via* FORMULATION =' DISCRETE '. It is available with or without Coulomb friction.
2) Formulations on the XFEM elements (see [R 7.02.12] for the small sliding version and [R 5.03.53] for the large sliding version) which are a variation of the continuous formulation to the case of XFEM elements. These formulations are accessible *via* FORMULATION = «XFEM». They are available with or without Coulomb friction.
3) The continuous formulation (see [R 5.03.52]) which is a method of Augmented lagrangian written using the mixed variational formulation «multiplying displacements/contact pressure/of friction». This formulation is performed *via* FORMULATION = «CONTINUE». It is available with or without Coulomb friction.

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4) The unilateral link (FORMULATION = «LIAISON_UNIL»). Pres to the discrete formulations, it is based on an algorithm used in contact imposing inequality type boundary conditions on any degree of freedom. This formulation is treated separately in the last part of this document (*cf.* §3.6).

Before doing a computation with contact, it is **essential** to have read the user guide of the contact [U 2.04.04] which explicit 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 resolution methods of contact-friction known as meshed formulations (discrete formulations [R 5.03.50] or formulation continuous [R 5.03.52]) are based on a two time strategy:

- a pairing operation which consists in finding which meshes and which nodes are potentially in situation of contact;
- a resolution operation which consists in solving the problem of unilateral contact with or without friction.

Paragraphs 3.1 and 3.2 focus on the pairing while the paragraphs 3.3 and 3.4 resolution methods of the problem treat.
Finally the paragraph 3.5 described the post-processing part, produced by a computation with contact.
The formulation «LIAISON_UNIL» is approached in the paragraph 3.6.

3.1 Pairing control (meshed methods out OF xfem)

♦ ZONE = _f (*options of pairing*)

The keywords of this paragraph are valid for the meshed formulations (DISCRETE and CONTINUE).

3.1.1 Operand APPARIEMENT

```
◊  APPARIEMENT     =  /'MAIT _ESCL»                        [DEFAUT]
                      /'NODAL»
```

In the case as of discrete formulations pairing can be node- facet («MAIT_ESCL») or nodal («NODAL»). For nodal pairing one writes a relation of nonpenetration between a master node and a slave node, whereas for pairing node- facet one writes this relation between a slave node and its projection on the nearest Master mesh (see [R 5.03.50] for details on the pairing algorithm).

Nodal pairing is reserved for the compatible meshes and is only available in formulation DISCRETE. Master-slave pairing is the only method to make it possible to take into account the great sliding in an accurate way.

3.1.2 Operands MAILLE_MAIT/GROUP_MA_MAIT/MAILLE_ESCL/GROUP_MA_ESCL

```
♦ /GROUP_MA_MAIT   = l_grma_mait                        [] l_gr_maille
  /MAILLE_MAIT     =  l_maille_mait                     [l_maille]
♦ /GROUP_MA_ESCL   =  l_grma_escl                       [] l_gr_maille
  /MAILLE_ESCL     =  l_maille_escl                     [l_maille]
```

For the meshed formulations the user provides the list of potential contact mesh of the Master surface (GROUP_MA_MAIT or MAILLE_MAIT) and of slave surface (GROUP_MA_ESCL or MAILLE_ESCL). These meshes must be surface or linear in dimension 3 (QUAD9, QUAD8, QUAD4, TRIA7, TRIA6, TRIA3, SEG3, SEG2), linear or punctual 2 (SEG3, SEG2 and POI1).

Warning :

– *It is important to check that the connectivity of these meshes is such as* ***the structure normal is outgoing*** *(with this intention, use MODI_MAILLAGE keyword ORIE_PEAU_2D, ORIE_PEAU_3D, ORIE_NORM_COQUE [U 4.23.04]).*

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– The intersection between a Master and a slave surface of the same zone must be disconnected or the common nodes must be excluded (cf. 3.1.3).
– Slave surfaces must be imperatively disconnected in continuous formulation.

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

Notice :

• It is impossible to mix purely two-dimensional modelizations (plane stresses C_PLAN, plane strains D_PLAN and axisymmetric AXIS) with the three-dimensional modelling. Master and slave surfaces 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 shell are of dimension 3 and it is thus possible to make contact poutre/3D or beam/plate.
• In 3d, it is not possible to define contact zones with a slave surface of the type SEG2 or SEG3 , which excludes the case from a contact between two beam elements or cables.

3.1.3 Operands SANS_NOEUD/SANS_GROUP_NO/SANS_MAILLE/SANS_GROUP_MA

```
◊  SANS_GROUP_NO    =  l_sgrno                          [] l_gr_noeud
◊  SANS_NOEUD       =  l_snoeud                         [] l_noeud
◊  SANS_GROUP_MA    =  l_sgrma                          [] l_gr_maille
◊  SANS_MAILLE      =  l_smaille                        [l_maille]
```

These operands allow to exclude nodes from slave surfaces, 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_APPA/DIRE_APPA

```
◊  TYPE_APPA     =  /'PROCHE»                           [DEFAUT]
                    /'FIXE»
◊  DIRE_APPA     =  (Yx, Yy, Yz)                        [R]
```

The choice of the master mesh paired with a slave node is done by a minimization operation of the distance between this node and the Master elements. With the default option, TYPE_APPA =' PROCHE ', the algorithm used for this orthogonal projection is a conventional Newton's algorithm.
In very rare cases this algorithm can fail, for example if projection on a mesh is not single, which can occur if the Master mesh is convex. In this case, the user can give a fixed pairing direction to use in the algorithm *via* the option TYPE_APPA =' FIXE ', direction being then given by a vector in DIRE_APPA.

3.1.5 Operands TOLE_APPA and TOLE_PROJ_EXT

```
◊  TOLE_APPA       =  /-1.0                             [DEFAUT]
                      /tole_appa                        [R]
◊  TOLE_PROJ_EXT   =  /0.50                             [DEFAUT]
                      /tole_proj_ext                    [R]
```

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

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= val with val a positive real, then only the Master meshes located, in 3d in the sphere, in 2d in the circle of radius val central (E) on the slave node can be paired.

In certain situations, it can be necessary to extend in a fictitious way the meshes of the Master surface. Let us consider the case of the 2d contact on Figure 3.1.5-1 (contact surfaces are thus segments), we are on the edge of the contact surface. The projection of a slave node falls apart from the Master surface.

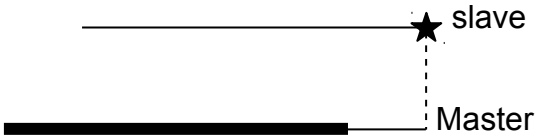

Figure 3.1.5-1: Projection of a slave node apart from a Master mesh

A solution consists in not pairing the node, which means to exclude it from contact:

Figure 3.1.5-2: Exclusion of a slave node

However, this solution does not take into account borderline cases and can cause interpenetrations if ever the mesh is not «optimal» (i.e. not enough fine, which is difficult to ensure in the frame of the large transformations). *Conversely*, one can obviously not turn down all the nodes projecting itself outside the Master surface.
Thus one chose an intermediate solution by limiting the expansion of the Master surface likely to involve a folding back.

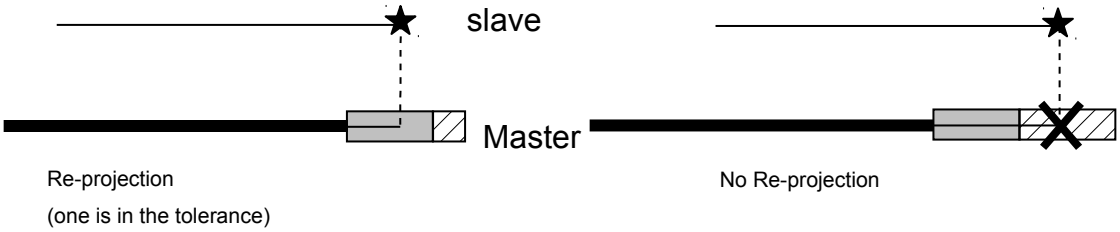

Figure 3.1.5-3: Operation of TOLE_PROJ_EXT

The size of the folding back is fixed the keyword «TOLE_PROJ_EXT» which takes for argument the value, reported to the reference element, of the expansion of the Master mesh. By default, this value is 0.50. For example in 2d, it means that any slave node projecting himself with more than 25% on the right or on the left the length of the Master mesh will not be folded back (in the case of a segment, the reference element is length 2, cf [R 3.01.01]). To prohibit it completely folding back, it is enough to fix TOLE_PROJ_EXT negative. This operator is valid in 2d and 3d (in this last case, it is the expansion of a contact surface mesh).

Notice :

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

3.1.6 Choice of the norms

3.1.6.1 Type of normal (NORMALE)

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```
◊  NORMALE          =  /'MAIT»                                  [DEFAUT]
                       /'MAIT _ESCL»
                       /'ESCL»
```

It is possible to choose the type of the norm used to write the non-interpenetration conditions:

- the norm external with the Master mesh (NORMALE =' MAIT», by default);
- the internal norm to the slave mesh (NORMALE =' ESCL»);
- an average between the Master and slave norms (NORMALE =' MAIT_ESCL ').

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

```
◊  VECT_MAIT        =  /'AUTO»                                  [DEFAUT]
                       /'FIXE»
                       /'VECT _y»
♦  MAIT_FIXE        =  (Yx, Yy, Yz)                             [R]
♦  MAIT_VECT_Y      =  (Yx, Yy, Yz)                             [R]

◊  VECT_ESCL        =  /'AUTO»                                  [DEFAUT]
                       /'FIXE»
                       /'VECT _y»
♦  ESCL_FIXE        =  (Yx, Yy, Yz)                             [R]
♦  ESCL _VECT_Y     =  (Yx, Yy, Yz)                             [R]
```

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

- automatically, the normal is then calculated by the use of the shape functions of the element, it is the option «AUTO» ;
- fixed and directly given by the user, the option ' FIXE». We write then the norm with the keyword MAIT_FIXE or ESCL_FIXE ;
- variable and directly given 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 cross 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 norm 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 deformed only in the plane. In this case, the use of the option of the type VECT_Y allows to update continuously the norm while the beam is distorting:

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

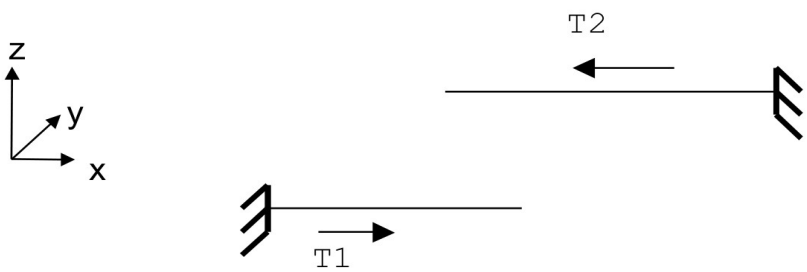

Figure 3.1.6.2-1: Determination of the normal by VECT_Y

In the example above, T1 = (1,0,0) and T2 = (- 1,0,0), with VECT_Y = (0,1,0), we obtain the desired norm for each beam: N1 = (0,0,1) and N2 = (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 [U 4.23.04].

3.1.6.3 Smoothing of the norms (LISSAGE)

```
◊  LISSAGE          =  /'NON»,                          [DEFAUT]
                       /'OUI»,
```

The operand LISSAGE allows to smooth the norms on the contact surfaces occuring in the computation of the contact matrix. One will note Q an unspecified node of contact surfaces (master or slave), P a node of the slave surface and M the master 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 at the node Q norms with the meshes which contains Q ;
- the second stage consists in the interpolating norm in P or M starting from the norms in Q and of the shape functions associated with the mesh containing P or M .

Lissage takes into account the options of norms decided by the keywords VECT_MAIT and VECT_ESCL. Caution, this parameter is global and not area.

3.1.7 Modification of clearance

The gap is always computed as being the minimal distance between the slave node and projection on the nearest Master mesh, modulo the options of choice of this normal (*cf.* 3.1.6). However it is possible to define values of clearance entered explicitely, for example, to simulate the presence of a hole or a bump not represented by the mesh, or to take into account the geometrical characteristics of the structural elements which use the concept of fiber neutral or mean 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 non-meshed fictious clearance or the thickness of shells for example (by default the relations of contact are written between the parts meshed i.e. between the two average slips).
This clearance is taken into account on the Master surfaces (DIST_MAIT) or slave (DIST_ESCL). One positively counts the distance in the direction of the outbound normal to the structure (cf [R 5.03.50]). A negative value thus makes it possible to «dig» virtually a surface (Master or slave). Contrary, a positive value allows to» enlarge» a surface.
The well informed quantities are necessarily functions of the variables of space or time ($X, Y, Z, INST$). If the user wants a fixed value, it must define a constant function (see DEFI_CONSTANTE [U 4.31.01]).

3.1.7.2 Operands DIST_POUTRE/DIST_COQUE/CARA_ELEM

```
◊  DIST_POUTRE      =  /'NON»                           [DEFAUT]
                       /'OUI»
◊  DIST_COQUE       =  /'NON»                           [DEFAUT]
                       /'OUI»
♦  CARA_ELEM        =  carac                            [cara_elem]
```

Similar to the two preceding keywords, keywords DIST_POUTRE/DIST_COQUE allow to introduce a fictitious clearance which leans on the description of the structural elements in the concept produced by AFFE_CARA_ELEM that the user has compulsorily given:

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- for the beam elements (modelization POU_ *), the keyword DIST_POUTRE stipulate that the code must take account of an extra clearance corresponding to the radius of the section **circular** beam.
- for plate or shell elements (modelization DKT or COQUE_3D for example), the keyword DIST_COQUE stipulate that the code must take account of an extra clearance corresponding to the half-thickness around the average layer of a shell.

Caution, when these keywords are used, fictitious clearance is added only on the slave surface. If a contact between two structural elements, it will thus be necessary also to use DIST_MAIT.

3.2 Specific pairing control to the formulation CONTINUE

3.2.1 Operands SANS_NOEUD_FR/SANS_GROUP_NO_FR

```
◊  /SANS_NOEUD_FR      =  l_sfnoeud                          [] l_noeud
   /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 friction of the slave nodes support boundary conditions in conflict with the imposition of adherence and sliding. The excluded nodes continue to verify the contact conditions.
In 2d, no other key word 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 plane to the contact points is excluded. Adherence or sliding will be occur thus only in the perpendicular direction (in the tangent plane).

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

Notice :

- *The exclusion of nodes is not possible that with the integration scheme by default (cf § 3.4.2.3)*

3.3 Choice and control of the global algorithm of resolution

3.3.1 Geometrical non-linearity control

Whatever the formulation is used, it is necessary to treat the geometrical non-linearity of the contact-friction problem. 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 «point fixe» (ALGORITHME_RESO_GEOM =' POINT_FIXE '). The formulation CONTINUE is also able to treat geometrical non-linearity with the Newton algorithm (ALGORITHME_RESO_GEOM =' NEWTON ', to see §3.3.4.4).
In formulation XFEM, the choice to activate the geometrical reactualization or not switches towards two distinct formulations (see [R 5.03.53]): X-FEM small sliding or X-FEM large sliding.

When geometrical non-linearity is solved by a loop of «point fixe», a certain number of adjustments are possible:

```
◊  REAC_GEOM        =  /'AUTOMATIQUE»,                       [DEFAUT]
                       /«CONTROLE»,
                       /'SANS»
◊  ITER_GEOM_MAXI   =  /10,                                  [DEFAUT]
                       /iter_geom_maxi,                      [I]
```

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```
◊  RESI_GEOM        =  /0.01,                          [DEFAUT]
                       /0.0001,                        [DEFAULT] (XFEM)
                       /resi_geom,                     [R]
◊  NB_ITER_GEOM     =  /2,                             [DEFAUT]
                       /nb_iter_geom,                  [I]
```

The operand REAC_GEOM indicate on which geometrical configuration the contact problem is treated:

- REAC_GEOM =' AUTOMATIQUE ' : the geometry automatically is reactualized i.e. that the number of cycles «reactualization geometrical-iterations» until convergence is not fixed in advance but geometrical convergence criterion. It is the default option, advised to solve the non-linearity of pairing correctly. It ensure that the contact conditions have been imposed on an initial configuration which differs less resi_geom found configuration (1% by default for the formulations DISCRETE or CONTINUE, 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 perturbations or when the normal on the contact surfaces does not change during the computation.

- REAC_GEOM =' CONTRÔLE ' : when the automatic criterion does not manage to be reached, the user must control himself the geometrical reactualization and for this reason he has the parameter NB_ITER_GEOM. It is the number of geometrical updates cycles which will be carried out by load steps. We place at a load step:
  - Value 1 indicates that with Newton convergence, one updates the geometry and one passes to the next load step.
  - Value 2 indicates that with Newton convergence, one updates the geometry and one reiterates until convergence before passing to the next load step.
  - The value $n>2$ indicate that one makes n cycles «reactualization geometrical-convergence» before passing to the next load step.

If you selected REAC_GEOM =' AUTOMATIQUE ', the parameter ITER_GEOM_MAXI is the tolerated maximum number of geometrical updates cycles. 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 cut the time step if the user has asked it. Documentation [U 2.04.04] provides many advice to overcome these problems of convergence (in particular, to activating smoothing).

Remarks :

- *If the user chooses a controlled update 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 error (necessarily higher than 1%) is admissible or not. There is indeed a risk of error of pairing (a mesh was paired on a configuration which has moved) and thus interpenetration.*
- *If one solves on the initial geometry or with only one cycle of geometrical reactualization, there is no warning because one cannot compute error. The user must thus check the validity of its postprocessing choices.*
- *The value of the geometrical convergence criterion is displayed in the table of the iterations of Newton (column CONTACT VALUE CRITERION).*

3.3.2 Friction

```
◊  FROTTEMENT       =  /'SANS»,                        [DEFAUT]
                       /'COULOMB»,
```

To assign Coulomb friction to contact zones, use the keyword FROTTEMENT =«COULOMB». This keyword is **global** (valid for all areas), but it is possible to affect friction zone by while exploiting the value of the coefficient of Coulomb (this coefficient to 0 when one does not wishes friction).

3.3.3 Formulation DISCRETE

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3.3.3.1 Algorithms choices

```
    ♦ ALGORITHME_CONT        =   /'CONTRAINTE»
[DEFAUT]
                           /'GCP»
                           /'PENALISATION»
    ♦ ALGORITHME_FROT        =   /'PENALISATION»
[DEFAUT]
```

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

	ALGORITHME_FROT =' PENALIZATION '
ALGORITHME_CONT =' CONTRAINTE '	***Impossible***
ALGORITHME_CONT =' GCP '	***Impossible***
ALGORITHME_CONT =' PENALIZATION '	***OK***

The various resolution methods are:

- «CONTRAINTE» : algorithm par default which deals with the problem of the exact unilateral contact with the active stresses (see [R 5.03.50]). **No possible friction**.
- «GCP» : it is an iterative method close of the method «CONTRAINTE» but which is particularly adapted to the cases where the number of contact connections is very high. **No possible friction**.
- «PENALIZATION» : the penalized method makes it possible to treat contact problems in an approximate way with or without friction, in 2d or 3d.

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

3.3.3.2 Methods dualized (CONTRAINTE)

Method CONTRAINTE allows solving contact problems without friction in an exact way (no interpenetration is tolerated). It is particularly fast and robust, its convergence is proved. The resolution of the inequations system resulting from contact leaning on explicit construction of a Schur complement, its use is limited to a few hundred contact connection. Beyond the costs ratio and computation become too important.

```
◊  NB_RESOL        =  /10,                              [DEFAUT]
                      /nb_resol                         [I]
```

NB_RESOL is the number of simultaneous resolutions for the construction of the Schur complement. To achieve several simultaneous resolutions allow manipulating matrix per blocks. To increase nb_resol thus accelerate to the construction of the Schur complement but one lose memory. nb_resol= 10 is a good compromise. This parameter is reserved for **experts**.

```
◊  STOP_SINGULIER  =  /'OUI»,                           [DEFAUT]
                      /'NON»
```

STOP_SINGULIER allows to deactivate the fatal error appearing if the addition 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 reserved for **experts**.

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```
◊  ITER_CONT_MULT   =  /4,                                  [DEFAUT]
                       /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 contact statue will be equal to the product iter_cont_mult by the number of slave nodes.

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

Note: for the method CONTRAINTE, convergence being proved, this coefficient is fixed at 2.

3.3.3.3 Method GLISSIERE

```
◊  GLISSIERE        =  /'NON»                               [DEFAUT]
                       /'OUI»
◊  ALARME_JEU       =  /0                                   [DEFAUT]
                       /alarme_jeu                          [R]
```

This option is only available for the method »CONTRAINTE '. It makes it possible to activate the mode of bilateral contact also called «glissiere», in which two surfaces being in contact stay «stuck» (i.e. with zero clearance) whatever the evolution of the loading. It authorizes large relative sliding.
The bilateral contact is activated only once surfaces are indeed in contact (one does not stick *a priori* two separated surfaces if the loading does not imply it).
The operand «ALARME_JEU» allows off an alarm as soon as the algorithm detects that, without the glissiere method, there would be separation of two surfaces. Its value is adjusted by default to 0, which alarm the user as soon as surfaces should have been unstuck without the option activated.

3.3.3.4 Method GCP

This method allows solving contact problems without friction. It solves with an adjustable accuracy (possibly very high) the contact conditions using lagrange multipliers. It is in any point similar to the method «CONTRAINTE» with the difference close that it is of completely iterative and thus very little rebukes in memory. In other words, the overcost of storage related to the taking into account of contact is weak. This specificity means that this method is particularly adapted to the case implying a large number of contact connections.

```
◊  RESI_ABSO        =  /resi_abso                           [R]
◊  ITER_GCP_MAXI    =  /0                                   [DEFAUT]
                       /iter_gcp_maxi
◊  RECH_LINEAIRE    =  /'ADMISSIBLE»                        [DEFAUT]
                       /'NON _ADMISSIBLE»

◊  PRE_COND         =  /'SANS»,                             [DEFAUT]
                       /'DIRICHLET»
◊  ITER_PRE_MAXI    =  /0                                   [DEFAUT]
                       /iter_pre_maxi
◊  COEF_RESI        =  /-1.                                 [DEFAUT]
                       /coef_resi                           [R]
```

The keyword RESI_ABSO allows to tune the accuracy of the resolution of the inequations of contact (it is a stopping criteria on the value of clearances for the iterative algorithm). RESI_ABSO (that it is necessary to understand by «absolute residual») represents the maximum level of interpenetration tolerated for bodies in contact. From a practical point of view, one will start by choosing a value on 10^{-3} time the size of the elements in the vicinity of contact surfaces then one will decrease this value until stabilization of results.

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The maximum number of authorized iterations of the algorithm of the conjugate gradient projected can be structured with the keyword ITER_GCP_MAXI. By default this number of iterations depends on the size of the problem.

Like any iterative method of resolution, method «GCP» can be accelerated by the use of a pre-conditioner. Only one is available and it is about a pre-conditioner of Dirichlet (PRE_COND =' DIRICHLET '). Its use can in certain cases to accelerate and decrease appreciably the time of resolution. By default no pre-conditioner is activated (PRE_COND = «SANS»).
The phase of preconditioning 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 residual sufficiently decreased: more precisely when the initial residual 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 search. Two alternatives are available: admissible or not admissible. One chooses them with the keyword RECH_LINEAIRE (*cf.* [R 5.03.50]).

3.3.3.5 Method PENALIZATION

This method is a method of resolution of the contact/friction by regularization. It is not exact 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 give it (S) coefficient (S) of penalization (cf §3.4.1.1).

3.3.4 Formulation CONTINUE

3.3.4.1 Algorithms choices

```
◊  ALGORITHME_RESO_CONT   =  /'NEWTON»                    [DEFAUT]
                            /'POINT _FIXE»
◊  ALGORITHME_RESO_FROT   =  /'NEWTON»                    [DEFAUT]
                            /'POINT _FIXE»
◊  ALGORITHME_RESO_GEOM   =  /'POINT _FIXE»                  [DEFAUT]
                            /'NEWTON»
```

The continuous formulation has types of algorithms to solve contact-friction non-linearities: algorithm fixed-point or Newton algorithm. In addition to geometrical non-linearity (*cf.* §3.3.1), this choice can also be carried out for the non-linearity of contact and of friction *via* keywords ALGORITHME_RESO_CONT, ALGORITHME_RESO_FROT and ALGORITHME_RESO_GEOM (all the choices are not possible):

ALGORITHME_RESO_CONT	ALGORITHME_RESO_FROT	ALGORITHME_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***

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

Whatever the method of resolution used (fixed-point or Newton) the results obtained are identical.

3.3.4.2 Non-linearity of contact

```
◊  ITER_CONT_TYPE   =  /'MAXI»,                          [DEFAUT]
                       /'MULT»
◊  ITER_CONT_MULT   =  /4,                               [DEFAUT]
                       /iter_cont_mult,                  [I]
◊  ITER_CONT_MAXI   =  /30,                              [DEFAUT]
                       /iter_cont_maxi,                  [I]
```

With the adjustments by default (`ALGORITHME_RESO_CONT =' NEWTON '`), there is no parameter required for the resolution of the non-linearity of contact.
When one chooses `ALGORITHME_RESO_CONT =' POINT_FIXE '`, one can control the loop on the statutes of contact in two ways:

- 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 number of iterations on the contact statue will be equal to the product `iter_cont_mult` by the number of slave nodes.

In fixed point method, the statutes are changed per blocks and the maximum number of iterations is thus not indicated logically in absolute value. If the maximum number of iterations of contact is reached, one can then try to refine the mesh, to subdivide the time step or as a last resort to increase the value of `ITER_CONT_MAXI/ITER_CONT_MULT`.

3.3.4.3 Non-linearity of threshold of friction

```
◊  ITER_FROT_MAXI   =  /10,                              [DEFAUT]
                       /iter_frot_maxi,                  [I]
◊  RESI_FROT        =  /0.0001,                          [DEFAUT]
                       /resi_frot,                       [R]
◊  ADAPT_COEF       =  /'NON»                            [DEFAUT]
                       /'OUI»
```

By default the problem of Coulomb is solved by a generalized Newton algorithm (`ALGORITHME_RESO_FROT =' NEWTON '`), the only keyword which can inform is thus `RESI_FROT` to define the criterion of stationarity of the threshold (during `RESI_GEOM`, *cf.* 3.3.1). An extra 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 `ALGORITHME_RESO_FROT =' POINT_FIXE '`, the problem of Coulomb is solved by a sequel of fixed points on the threshold of Tresca. To control the loop, this mechanism is the same as on the loop of geometrical reactualization (*cf.* 3.3.1, `ITER_FROT_MAXI` play the part of `ITER_GEOM_MAXI` and `RESI_FROT` play the part of `RESI_GEOM`).

When one chooses `ADAPT_COEF = OUI`, one activates the possibility of controlling the coefficient of kinetic friction in increase (`COEF_ FROT`) by a method of cycling automatic processing (see [R

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5.03.52]). This option is to be activated in the event of difficulties of convergence if one uses the generalized Newton method, if a large number of cyclings occurs. The number of cyclings during an iteration is indicated in column *CONTACT INFO CYCLAGES* table of convergence.

3.3.4.4 Geometrical non-linearity

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

The parameters of the fixed-point loop on the geometry (parameter by default) are given in the § 3.3.1 .

When one chooses ALGO_RESO_ GEOM =' NEWTON ', one rocks towards the Newton algorithm. Geometrical non-linearity is then taken into account with each iteration of Newton: one remakes pairing and we recompute the local base (normal and tangent). 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 checked generally before the criterion of equilibrium Newton . If one wants to really to control it, it is thus necessary to shift in mode POINT_FIXE .

3.3.5 Formulation XFEM

3.3.5.1 Fixed point loop for the statutes of contact

```
◊  ITER_CONT_TYPE   =  /'MAXI»,                            [DEFAUT]
                       /'MULT»
◊  ITER_CONT_MULT   =  /4,                                 [DEFAUT]
                       /iter_cont_mult,                    [I]
◊  ITER_CONT_MAXI   =  /30,                                [DEFAUT]
                       /iter_cont_maxi,                    [I]
```

One can control the loop on the statutes of contact in two ways:
- 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 number of iterations on the contact statue will be equal to the product iter_cont_mult by the number of slave nodes.

For the formulation XFEM, the statutes are changed per blocks and the maximum number of iterations is thus not indicated logically in absolute value. In all 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 mesh, to subdivide the time step or as a last resort to increase the value of ITER_CONT_MAXI/ITER_CONT_MULT.

3.3.5.2 Fixed point loop for friction

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

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

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For X-FEM in large sliding (REAC_GEOM! = «SANS»), there is no loop on the thresholds of Tresca (Newton algorithm). The parameter ITER_FROT_MAXI no effect has then.

3.3.5.3 Management of the redundant boundary

```
◊   ELIM_ARETE      =   /'DUAL»,                          [DEFAUT]
                        /'ELIM»
```

In the theoretical documentation of XFEM with taking into account of the contact/friction [R 5.03.04], one explains the importance to eliminate some edges size 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 shape and the redundant degrees of freedom are eliminated from the unknowns, which is more effective (models least large, 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» .

3.3.6 Without solving method

```
◊   STOP_INTERP     =   /'NON»,                           [DEFAUT]
                        /'OUI»
```

In the case of mode without resolution (see §3.4.4) the code emits an alarm as soon as it detects an interpenetration. The parameter STOP_INTERP allows to stop the computation instead of alarming the user.

3.4 Local parameters (zone by zone) of the resolution

3.4.1 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 area.

3.4.1.1 Method «PENALIZATION»

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

e_n is the coefficient of penalization on the interpenetration for the penalized method. It is homogeneous with the stiffness of springs placed between contact surfaces to prevent the interpenetration. A value on the largest Young modulus of solids in contact multiplied by a characteristic length is first advised. 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 areas 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 contact zones.
There exists in formulation DISCRETE an automatic adaptation mechanism of the coefficient of penalization E_N (*cf.* DEFI_LISTE_INST [U 4.34.03]).

e_t is the coefficient of penalization on the sliding 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.

3.4.1.2 Specific parameters for friction

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

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The parameter COULOMB allows to tune 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 sliding (which is added to tangent stiffness, *cf.* [R 5.03.50]). More this coefficient is large, better is convergence when one is close to the equilibrium and more the resolution is difficult far from the equilibrium. A value of 0.5 is thus a good compromise. The default value fixed at 0 ensures a better robustness for a longer cpu- time.

3.4.2 Local parameters (zone by zone) of the formulation CONTINUE

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

The keywords of this paragraph are valid for the formulation CONTINUE. The parameters are defined by area.

3.4.2.1 Operands CONTACT_INIT/SEUIL_INIT

```
◊   CONTACT_INIT     =   /'INTERPENETRE»                          [DEFAUT]
                         /'OUI»
                         /'NON»
◊   SEUIL_INIT       =   /0.                                      [DEFAUT]
                         /seuil_init                              [R]
```

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

By default, only connections with zero clearance or interpenetrated are activated by the algorithm (CONTACT_INIT =' INTERPENETRE '). Nevertheless it is possible to the force algorithm to activating all connections without exception (CONTACT_INIT = OUI). The value CONTACT_INIT =' INTERPENETRE ' is compulsory in the event of resumption of computation with an initial state. It is also possible to deactivate any initial contact by CONTACT_INIT =' NON '.

Regarding the friction, the user can specify, if it wants, the value of the initial threshold (if it wants an initial adherent contact for example). The threshold of sliding has the dimension of a surface force per unit area. In a point of contact surface, there will be sliding if the contact pressure λ and the coefficient of friction μ check: $\lambda \geqslant \mu \times SEUIL\_INIT$. The value which it will have chosen will apply to all the points of the contact zone concerned. If no value is then indicated the behavior by default of SEUIL_INIT is such as:
– if it is of a resumption of computation or a computation 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 to zero and all the points are potentially slipping.

3.4.2.2 Coefficients of the formulation CONTINUE

```
 ◊ ALGORITHME_CONT        =   /'STANDARD»                          [DEFAUT]
                         /'PENALISATION»
{If ALGO_CONT = =   «STANDARD»
      ♦  COEF_CONT =   /100.                              [DEFAUT]
                       /coef_cont                         [R]
}
{If ALGO_CONT = =   «PENALIZATION»
      ♦  COEF_PENA_CONT = coef_pena_cont                     [R]
}

◊   ALGO_ FROT       =   /'STANDARD»                        [DEFAUT]
                         /'PENALISATION»
```


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```
{If ALGO_FROT = =   «STANDARD»
      ♦  COEF_FROT =  /100.                          [DEFAUT]
                      /coef_frot                     [R]
}
{If ALGO_FROT = =   «PENALIZATION»
      ♦  COEF_PENA_ FROT= coef_pena_frot             [R]
}
```

The continuous formulation is an augmented Lagrangian formulation. There is a penalized version.
If one chooses ALGORITHME_CONT =' STANDARD ' and ALGORITHME_FROT =' STANDARD ', the continuous formulation is then equivalent to a conventional augmented Lagrangian formulation of which the increase coefficients are given, respectively, by COEF_CONT and COEF_FROT.
If one chooses ALGORITHME_CONT =' PENALIZATION ' and ALGORITHME_FROT =' PENALIZATION ', the formulation is then 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 to §3.3.3.5 and §3.4.1.1, COEF_PENA_CONT corresponds to it to E_N and COEF_PENA_FROT with E_T.

It is not possible to mix a standard formulation for the contact and penalized for friction and *vice versa* .

3.4.2.3 Operand INTEGRATION

```
◊  INTEGRATION      =  /'AUTO»                         [DEFAUT]
                       /'GAUSS»
                       /'SIMPSON»
                       /'NCOTES»

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

The operand «INTEGRATION» allows to select a numerical integration method for the terms of contact and friction. Several methods are implemented:
– «AUTO» to let the code choose the integration scheme more adapted (trapezoidal type or Simpson);
– «GAUSS» for of a gauss quadrature with the possibility of choosing the degree of the polynomials which the scheme makes it possible to integrate exactly;
– «SIMPSON» for a scheme of Simpson ($1/3$) with the possibility of choosing the number of subdivisions of the reference element;
– «NCOTES» for a scheme of Newton-Cotes with the possibility of choosing the degree of the polynomials interpolation.

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

Integration automatic (choice by default) is the most general and most effective. The choice of a scheme of integration is reserved for **experts**.

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3.4.2.4 Operand GLISSIERE

```
◊  GLISSIERE        =  /'NON»                                  [DEFAUT]
                       /'OUI»
```

Contrary to the discrete formulation (see §3.3.3.3), it is possible to activate this option areas by area.

3.4.3 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 area.

3.4.3.1 Operand FISS_MAIT

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

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 [U 4.82.08].

3.4.3.2 Operands CONTACT_INIT/SEUIL_INIT

```
◊  CONTACT_INIT     =  /'NON»                                  [DEFAUT]
                       /'OUI»
◊  SEUIL_INIT       =  /0.                                     [DEFAUT]
                       /seuil_init                             [R]
```

Cf. 3.4.2.1.

3.4.3.3 Coefficients of the formulation XFEM

```
◊  ALGORITHME_CONT        =  /'STANDARD»
[DEFAUT]
                       /'PENALISATION»
                       /'CZM»
◊  COEF_CONT        =  /100.                                   [DEFAUT]
                       /coef_cont                              [R]
◊  COEF_PENA_CONT   =  /100.                                   [DEFAUT]
                       /coef_pena_cont                         [R]
◊  ALGORITHME_FROT        =  /'STANDARD»
[DEFAUT]
                       /'PENALISATION»
◊  COEF_FROT        =  /100.                                   [DEFAUT]
                       /coef_frot                              [R]
◊  COEF_PENA_FROT   =  /100.                                   [DEFAUT]
                       /coef_pena_frot                         [R]
```

The formulation XFEM is writing of a continuous type. The choice of the coefficients is the same as in the case of the formulation (§ continuous3.4.2.2).

The algorithm ALGORITHME_CONT = «CZM» (Cohesive Zone Model) 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 behavior of friction should not be indicated then. Indeed, the parameter COEF_PENA_CONT is for example useless, the coefficient of penalization being given starting from the material parameters provided in the operator

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DEFI_MATERIAU [U 4.43.01], under the keyword RUPT_FRAG. The shear stress obeying the cohesive model and not a friction law, no keyword relating to friction is used.

3.4.3.4 Operand INTEGRATION

```
 ◊ INTEGRATION      =  /'NOEUD»                                  [DEFAUT]
                       /'GAUSS»
                       /'SIMPSON»
                       /'NCOTES»

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

This keyword has the same meaning as that of the formulation CONTINUE, *cf.* §3.4.2.3. It is a parameter reserved for **experts**.

3.4.3.5 Operand GLISSIERE

```
◊  GLISSIERE       =  /'NON»                                    [DEFAUT]
                      /'OUI»
```

Contrary to the discrete formulation (see § 3.3.3.3), it is possible to activate this option areas by area.

3.4.3.6 Operand ALGORITHME_LAGR

```
    ◊  ALGORITHME_LAGR        =  /'AUTO»
[DEFAUT]
                          /'VERSION 1»
                          /'VERSION 2»
                          /'VERSION 3»
                          /'NON»
```

This keyword determines the choice of the algorithm of elimination of Lagrange of friction to satisfy condition LBB (see [R 7.02.12]). This parameter is of a use intended for **experts**. When the keyword «AUTO» is activated, for quadratic elements with REAC_GEOM = = «SANS», one rocks on ALGORITHME_LAGR = = «VERSION3». In all the other cases, one activates ALGORITHME_LAGR = = «VERSION2».

3.4.3.7 Operand RELATION

```
 ◊  RELATION        =  /'CZM _EXP_REG»                           [DEFAUT]
                       /'CZM _LIN_REG»
                       /'CZM _TAC_MIX»
                       /'CZM _OUV_MIX»
                       /'CZM _LIN_MIX»
```

The keyword RELATION allows to activate the taking into account of cohesive forces at the time of the opening of X-FEM interface. It is used exclusively with the option ALGORITHME_CONT ='CZM«.

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Cohesion is modelled by the cohesive model of the same name, already existing of conventional finite element method (see the user guide [U 2.05.07] for a summary, documentation [R 7.02.11] for the definition of these models and documentation [R 5.03.54] for their expansion 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 model (perfect initial bond used) with linear elements.
The necessary data of the material field are provided in the operator DEFI_MATERIAU [U 4.43.01], under the keyword RUPT_FRAG.

3.4.4 Without solving method

```
◊ RESOLUTION      =  /'OUI»,                          [DEFAUT]
                     /'NON»

◊ TOLE_INTERP     =  /0. ,                            [DEFAUT]
                     /tole_interp                     [R]
```

When RESOLUTION =' NON ', 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 time step of loading. The total parameter STOP_INTERP (§3.3.6) allows to stop the computation 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 mesh). The value given is absolute (does not have sign). This method is available in discrete and continuous formulation.

Remarks :

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

3.5 Field CONT_NOEU

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

- CONT : indicator of contact rubbing
  - -1 : the node (or the integration point) is not paired (for example out of the Master mesh, 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 ');
- JEU : value of clearance
- LAGRANGE : normal reaction of contact norm
- RNX : component according to DX normal reaction of contact

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- RNY : component according to DY normal reaction of contact
- RNZ : component according to DZ normal reaction of contact
- GLIX : component according to t_1 tangencial sliding (local coordinate system)
- GLIY : component according to t_2 tangencial sliding (local coordinate system)
- GLI : tangencial sliding
- RTAX : component according to DX tangencial force of adherence
- RTAY : component according to DY tangencial force of adherence
- RTAZ : component according to DZ tangencial force of adherence
- RTGX : component according to DX tangencial force of sliding
- RTGY : component according to DY tangencial force of sliding
- RTGZ : component according to DZ tangencial force of sliding
- 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 norm
- 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
- PROJ_X : coordinates according to DX projection of the slave node on the mesh or the master node
- PROJ_Y : coordinates according to DY projection of the slave node on the mesh or the master node
- PROJ_Z : coordinates according to DZ projection of the slave node on the mesh or the master node

Remarks :

- *in formulation «CONTINUE» , this field is produced only with the integration scheme by default (cf § 3.4.2.3);*
- *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 =' INFO FROTTEMENT ',
                        GROUP_NO =' ESCLAVE ',
                        RESULTAT = U,
                        INST = 10.,
                        TOUT_CMP = OUI,
                        NOM_CHAM =' CONT_NOEU ',
                        OPERATION =' EXTRACTION ',),);

IMPR_TABLE (TABLE = MATABLE);
```

It is to be noticed that the quantities corresponding to the reactions of friction are nodal forces (in unit force) within the meaning of the finite elements and not of contact pressures. In axisymmetric modelling, 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.* [U 4.81.02]). The nodal forces punctually did not have a meaning (they depend on the smoothness of the mesh), only their resultant can be interpreted.

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More generally, to have access to contact pressures, refer to the user guide of the contact [U 2.04.04] which describes the ways to recover them when they are produced by computation or to rebuild them in the contrary case.

3.6 Formulation LIAISON_UNIL

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…) (§3.6.1.3)
– $\alpha_i(t)$ a real function of time (parameter INST) (§3.6.1.4)
– $r(x, y, z, t)$ a real function of time (or space parameters X, Y, Z, INST) (§3.6.1.4)

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

3.6.1 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 area.

3.6.1.1 Operands MAILLE/GROUP_MA/NOEUD/GROUP_NO

```
♦ /GROUP_NO      =  l_grno                          [] l_gr_noeud
  /NOEUD         =  l_noeud                         [] l_noeud
  /GROUP_MA      =  l_grma                          [] l_gr_maille
  /MAILLE        =  l_maille                        [l_maille]
```

The unilateral condition is expressed on the nodes of the mesh given under the keywords GROUP_NO or NOEUD. One can nevertheless give the meshes carrying the nodes thanks to the keywords GROUP_MA and MAILLE. Contrary to the case of the «conventional» contact, as the conditions are nodal, it is useless to direct the normals to the meshes of skin in the case LIAISON_UNIL.

3.6.1.2 Operands SANS_NOEUD/SANS_GROUP_NO

```
◊ SANS_GROUP_NO  =  l_sgrno                         [] l_gr_noeud
◊ SANS_NOEUD     =  l_snoeud                        [] l_noeud
```

These operands allow to exclude nodes of the unilateral condition in the same way as for the formulations CONTINUE or DISCRETE (see §3.1.3).

3.6.1.3 Operand NOM_CMP

```
♦ NOM_CMP        =  l_cmp                           [l_TXM]
```

List of 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.

3.6.1.4 Operands COEF_IMPO and COEF_MULT

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- 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 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 be of course identical.
Coefficients $r(t)$ and $\alpha(t)$ are inevitably **functions**. To define constant coefficients, it will be advisable to use the command DEFI_CONSTANTE.

3.6.2 Example

The goal is to impose the condition 1.3 * PRE 1-5.2 * 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 = ('PRE 1», «PRE2»)
COEF_IMPO = coef_i
COEF_MULT = (coef_m1, coef_m2)
```

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