Code_Aster

Version default

Titre : Opérateur POST_K1_K2_K3
Responsable : Samuel GENIAUT

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Operator `POST_K1_K2_K3`

1 Drank

Compute the factors of intensity of the stresses in 2D and 3D.

This operator allows to calculate $K1$, $K2$ in 2D (plane and axisymmetric) and $K3$ in 3D by extrapolation of the jumps of displacements on the lips of crack, cf [R7.02.08]. This method is applicable only for the homogeneous and isotropic materials.

This operator is usable as well for a crack with a grid as for a crack nonwith a grid (method X-FEM). In the case of a crack with a grid, this one must obligatorily be plane.

The method used is theoretically less precise and more sensitive to the mesh than computation from the form bilinear of the rate of refund of energy and singular displacements, usable in 2D and 3D with option `CALC_K_G` of operator `CALC_G` [U4.82.03]. It however makes it possible to easily obtain a good estimate of the factors of intensity of the stresses.

Product a concept of the type `counts`.

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2   Syntax

```
tk   [array] = POST_K1_K2_K3          (

    ♦MODELISATION=/                   "3D",
                         /   "AXIS",
                         /   "D_PLAN",
                         /   "C_PLAN",


    ♦   MATER=mat                     ,              [material]

        ♦/FOND_FISS          =fond ,                    [fond_fiss]
         /   CRACK         =fiss ,                      [fiss_xfem]
        ◊ABSC_CURV_MAXI=dmax          ,                    [R]

# 1) If FOND_FISS is indicated:

        ♦   RESULTAT=resu          ,                /  [evol_elas]
                                                    /  [evol_noli]
                                                    /  [mode_meca]
        ◊/     TOUT=             `OUI',
           / | NOEUD=noeu           ,                    [l_noeud]
             | GROUP_NO=gr_noeu        ,                 [l_gr_noeud]
           / | SANS_NOEUD=noeu        ,
   [l_noeud]
             | SANS_GROUP_NO=gr_noeu   ,                 [l_gr_noeud]

        # If modelization 3D
        ◊   TYPE_MAILLAGE       =       "REGLE",                [DEFAULT]
                                /   "LIBRE",
        # Finsi
        ◊NB_NOEUD_COUPE=/5             ,
                              /n ,                       [I]
        ◊   PREC_VIS_A_VIS=/1.E-1             ,
   [DEFAULT]
                              /epsi ,                    [R]
        ◊   EVOL_THER=resuth           ,                 [evol_ther]


   # 2) If CRACK is indicated:

        ♦   RESULTAT=resu          ,                /  [evol_elas]
                                                    /  [evol_noli]
        ◊NB_NOEUD_COUPE          =/5   ,                 [DEFAULT]
                              /n ,                       [I]
        ◊NB_POINT_FOND=/nbnofo                ,          [I]
        ◊NUMÉRIQUE_FOND         =/1    ,                 [DEFAULT]
                              /numfon   ,                [I]

   # 3) FIN

                ◊/TOUT_ORDRE=' OUI',
        /   NUME_ORDRE=lnuor          ,                  [L_I]
        /LIST_ORDRE           =lnuor ,                   [listis]

        /TOUT_MODE           =   ' OUI',
```

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```
            /   NUME_MODE        =lnuor ,                      [L_I]
            /LIST_MODE           =lnuor ,                      [listis]

            /FREQ                 =l_freq ,                    [l_R]
            /LIST_FREQ             =l_freq ,                     [listR8]
            /INST                 =l_inst ,                    [l_R]
            /LIST_INST             =l_inst ,                     [listR8]
                ◊CRITERE=/            "RELATIF",
    [DEFAULT]

                       ◊   accuracy =   prec,      [R]
                                    /1.E-6 ,       [DEFAULT]
                  /   "ABSOLU",
                       ♦   accuracy =prec ,        [R]


        ◊TITER=titer                  ,                      [l_Kn]

        ◊INFO=/1                     ,


    )
```

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3   Operands

3.1   Operand MODELISATION

♦MODELISATION =   "3D",
/   "AXIS",
/   "D_PLAN",
/   "C_PLAN",

Allows to define the type of computation to be carried out: 3D (in which case one will calculate $K3$) or 2D. This modelization must be coherent with the model used for the computation of displacements.

3.2   Operand MATER

♦MATER=mat   ,   [material]

Concept of type material containing the elastic characteristics of the material fissured the material must be homogeneous, isotropic and elastic linear. This material must be **constant** (compulsory use of DEFI_MATERIAU/ELAS). The only tolerated dependence is the dependence with **the temperature**. If materials properties depend on the temperature (key word ELAS_FO of DEFI_MATERIAU), the processing is different according to the type of modelization:

- if operand EVOL_THER is not indicated, then the characteristic materials are obtained with reference temperature TEMP_DEF_ALPHA of DEFI_MATERIAU ;
- if operand EVOL_THER is indicated, then the characteristic materials are calculated from the temperature of the nodes of the crack tip.

3.3   Case where operand FOND_FISS is indicated

This case corresponds to a computation on a crack with a grid, definite for postprocessing with operator DEFI_FOND_FISS. By default, computation is made automatically for all the nodes of the crack tip.

3.3.1   Operands   FOND_FISS   /
PREC_VIS_A_VIS/NOEUD/GROUP_NO/SANS_NOEUD/SANS_GROUP_NO

◊FOND_FISS=fond   ,   [fond_fiss]
◊PREC_VIS_A_VIS=/1.D-1   ,   [DEFAULT]
/epsi ,   [R]
◊/TOUT=   `OUI',
/ | NOEUD=noeu   ,   [l_noeud]
| GROUP_NO=gr_noeu   ,   [l_gr_noeud]
/ | SANS_NOEUD=noeu ,   [l_noeud]
| SANS_GROUP_NO=gr_noeu ,   [l_gr_noeud]

operand FOND_FISS makes it possible to provide the concept fond_fiss (created by the command DEFI_FOND_FISS) in which are stored information necessary to the automatic search of the nodes of the two lips located on normal segments at the crack tip. Attention, the concept fond_fiss must necessarily be defined such as the lips of crack are initially stuck (CONFIGURATION_INIT=' COLLEE' in DEFI_FOND_FISS [U4.82.01])

In 3D, by default, the computation of the stress intensity factors is done only on the nodes tops of meshes composing the crack tip (thus all nodes for the linear elements, and a node on two for the quadratic elements). The user has the possibility of:

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- • to select some nodes tops of crack tip (key keys NOEUD and GROUP_NO);
- • to exclude from the nodes of the crack tip (key keys SANS_NOEUD and SANS_GROUP_NO);
- • to calculate on all the nodes mediums and tops of the crack tip (key word TOUT).

◊ABSC_CURV_MAXI=dmax   [R]

maximum Distance from computation of the factors of intensity of the stresses starting from the crack tip. In practice, the accuracy of the results is less good if one is located very far from the crack tip [R7.02.08]. It is thus advised to choose $dmax$ smallest possible (about 3 to 4 elements, or about the radius of the radiant mesh, if necessary). If in a point N of the crack tip, this distance is higher than the distance from the crack tip in this point at the edge of the lips, the value of the factors of intensity of the stresses at the point N are obtained by constant prolongation. The value selected is that of the point of the crack tip nearest and for which computation could be carried out.

Operand ABSC_CURV_MAXI is optional. When this operand is not indicated, the value of ABSC_CURV_MAXI automatically calculated starting from the maximum h of the sizes of meshes connected to the nodes of the crack tip. These sizes of meshes in each node of the bottom are calculated in command DEFI_FOND_FISS and are present in the concept fond_fiss [D4.10.01]. It was selected to take ABSC_CURV_MAXI equal to $4h$.

If one chooses the value automatically calculated for ABSC_CURV_MAXI, it is advisable however to make sure that its value (displayed in the file .mess) is coherent with dimensions of structure.

At the time of the automatic search for each node of the crack tip, the operator selects the nodes checking the following conditions:
- • outdistance R compared to the crack tip: R < ABSC_CURV_MAXI,
- • distance L compared to its opposite on the other lip:
$$L < \text{epsi.ABSC\_CURV\_MAXI},$$
- • and in 3D distance D from a node of the lips to the right perpendicular to the crack tip: D < epsi_fond . d, where d is the minimal distance between two successive nodes of the crack tip,
where epsi is the value of the provided accuracy (key word PREC_VIS_A_VIS) and epsi_fond the value of the accuracy provided in key word PREC_NORM of DEFI_FOND_FISS.

By default epsi is worth $0,1$. To increase the value of PREC_VIS_A_VIS (and/or PREC_NORM in DEFI_FOND_FISS) amounts increasing the number of nodes potentially retained for computation.

Note:

If TYPE_MAILLAGE= `REGLE', this accuracy intervenes in the phase of projection of result on the cut line: a point is regarded as being out of the matter if its distance to structure is higher than epsi.ABSC_CURV_MAXI. It can be necessary to modify the value by default of this parameter if the crack is represented by a notch.

3.3.2 Operands RESULTAT

♦ RESULTAT = resu,

resu is a concept of the evol_elas type, evol_noli or mode_meca containing the field of displacement on all the model.

Note:

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*resu can be a concept of the mode_meca type only if TYPE_MAILLAGE=
`REGLE'.*

3.3.3 Operand `TYPE_MAILLAGE`

◊TYPE_MAILLAGE = "REGLE",   [default]
/ "LIBRE",

This key word is available only in 3D, for cracks with a grid defined by `FOND_FISS`.

If `TYPE_MAILLAGE`= "REGLE", option to be used by default, computation is done by supposing that the nodes on the lips of crack are on normal directions at the bottom and exactly in with respect to a lip with the other. Alarm messages or of error are transmitted if it is not the case.

If the mesh does not meet these conditions, one can use option `TYPE_MAILLAGE='`
`LIBRE'`. The principle of computation is then the following:

1. determination of the normal directions at the crack tip for each node of the bottom,
2. definition on each one of these directions of `NB_NOEUD_COUPE` points équi-distribute between the bottom and the distance `ABSC_CURV_MAXI`,
3. projection of the displacement of each lip on these nodes,
4. interpolation of the jump of displacement.

The computation with `TYPE_MAILLAGE=' LIBRE'` can be less precise than computation by default.

3.3.4 Operand `NB_NOEUD_COUPE`

◊NB_NOEUD_COUPE=/5   ,   [DEFAULT]
/n ,   [I]

This operand intervenes only if `TYPE_MAILLAGE= `LIBRE'` is indicated. It makes it possible to define the number of nodes of projection of the displacement of the lips on each normal direction. The nodes of projection are équi-distribute between the crack tip and distance `ABSC_CURV_MAXI`.

Note:

The projection of the displacement of the lips on the NB_NOEUD_COUPE points of projection does not take correctly counts of it the displacement of the nodes to the quarter (elements of Barsoum). It is thus recommended not to use these elements if TYPE_MAILLAGE= `LIBRE'.

3.4 Case where the operand `CRACK` is indicated

This case corresponds to a computation on a crack nonwith a grid, definite for computation then for postprocessing with operator `DEFI_FISS_XFEM`.

3.4.1 Operand `FISSURES`

♦ CRACK = fiss,

Concept of the fiss_xfem type, produces DEFI_FISS_XFEM by the command.

3.4.2 Operand `RESULTAT`

♦ RESULTAT = resu,

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Concept of the evol_elas type or evol_noli containing the field of displacement on all the model. The mesh is deduced from this concept.

3.4.3 Operand `ABSC_CURV_MAXI`

◊ ABSC_CURV_MAXI=dmax   [R]

Outdistances maximum computation of the factors of intensity of the stresses starting from the crack tip. In practice, the accuracy of the results is less good if one is located very far from the crack tip [R7.02.08]. It is thus advised to choose $dmax$ smallest possible (about 4 to 5 elements. If in a point N of the crack tip, this distance is higher than the distance from the crack tip in this point at the edge of the lips, the value of the factors of intensity of the stresses at the point N are obtained by constant prolongation. The value selected is that of the point of the crack tip nearest and for which computation could be carried out.

Operand ABSC_CURV_MAXI is optional. When this operand is not indicated, the value of ABSC_CURV_MAXI automatically calculated starting from the maximum h of the sizes of meshes connected to the nodes of the crack tip. These sizes of meshes in each node of the bottom are calculated in command DEFI_FOND_FISS and are present in the concept fiss_xfem [D4.10.02]. It was selected to take ABSC_CURV_MAXI equal to $5h$.

If one chooses the value automatically calculated for ABSC_CURV_MAXI, it is advisable however to make sure that its value (displayed in the file .mess) is coherent with dimensions of structure.

3.4.4 Operand `NUME_FOND`

◊NUMÉRIQUE_FOND   =/1   ,   [DEFAULT]
                       /numfon   ,   [I]

Several crack tips can be defined in only one data structure of the fiss_xfem type. This operand makes it possible to select the number of the bottom on which computation must be carried out. By default, only the first bottom is considered.

3.4.5 Operand `NB_NOEUD_COUPE`

◊NB_NOEUD_COUPE=/5   ,   [DEFAULT]
               /n ,   [I]

This operand makes it possible to define the number of nodes of projection of the displacement of the lips on each normal direction. The nodes of projection are équi-distribute between the crack tip and distance ABSC_CURV_MAXI.

3.4.6 Operand `NB_POINT_FOND`

◊NB_POINT_FOND=/nbnofo   ,   [I]

By default for a crack X-FEM, computation gives a report on the crack tip on all the, i.e all the points of intersection between the crack tip and the edges of the mesh. Operand NB_POINT_FOND makes it possible to fix a priori the number of points of postprocessing, in order to limit the computing times. The nbnofo points are équi-distribute along the crack tip. Operands

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3.5 INST , LIST_INST , FREQ, LIST_FREQ, TOUT_ORDRE, NUME_ORDRE, LIST_ORDRE, TOUT_MODE, NUME_MODE, LIST_MODE cf

[U4.71.00]. Operand

3.6 INFO ◊

```
INFO  =/1,      [ DEFAULT                                   ] /2
              ,   Level
```

of messages in the message file: if INFO is worth 2, one provides the list of all the computed values for all the treated nodes. Operand

3.7 TITER ◊

```
TITER  = title, Title
```

which one wants to give to result of the command. Precautions

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4   and advice of Recall use

4.1   on the various methods used for extrapolation of the jumps of displacements [R7.02.08] In

each node of the crack tip, one uses 3 methods (alternatives) to determine, K_I (and K_{II} in K_{III} 3D). Method

- 1: for each node of the segment of interpolation, one calculates the jump of the field of displacements squared and one divides it par. r Various values of (resp $K1$., $K2$) $K3$ are obtained (except for a multiplicative factor) by extrapolation into cubes $r=0$ line segments thus obtained. Method
- 2: one traces the jump of the field of displacements squared according to. r The approximations of are $K1$ (always with a multiplicative factor near) equal to the slope of the segments connecting the origin to the various points of the curve. Method
- 3: linear regression. In

each node of the crack tip, each method provides a value MAX and a value MIN. In each node of the crack tip, one thus has 6 values for, K_I 6 values for and K_{II} 6 values for (for K_{III} method 3, the values MIN and MAX coincide). One notes these values as follows, the exhibitor corresponding j to the number of the method: for

- (mode K_I or I mode of opening): for $K_I^{j,MAX}, K_I^{j,MIN}$, $j=1,2,3$
- (mode K_{II} or II plane shears): and $K_{II}^{j,MAX}, K_{II}^{j,MIN}$, $j=1,2,3$
- for (mode K_{III} or III shears anti-plane):. $K_{III}^{j,MAX}, K_{III}^{j,MIN}$, $j=1,2,3$ Count

4.2   produced

command POST `_K1_K2_K3 produces` a concept of the type counts . The array can be printed by IMPR_TABLE [U 4.91.03]. It contains for each node of the crack tip:

- values of the stress intensity factors corresponding: K1 , K2 (and K3 so 3D)
- the value of rate of energy restitution: formulate G
- estimates of the error on the stress intensity factors: ERR _K1, ERR _K2 (and ERR _K3 so 3D).

The following paragraphs detail these quantities. Values

4.2.1   of the factors of intensity of the stresses

the produced array contains, for each node (or not) of the crack tip, the values of the stress intensity factors corresponding to values MAX of the method n°1 (see §4.19: ()

$$K1 \ , \ = K_I^{1,MAX} \ () \ K2 \ \text{In} \ = K_{II}^{1,MAX}$$

3D, one has in more (formula $K3 \quad = K_{III}^{1,MAX}$

thus prints only one value of, $K1$ (and $K2$ so $K3$ 3D) by node of the crack tip. Values

4.2.2   of rate of energy restitution

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the produced array contains, for each node (or not) of the crack tip, the value of the rate of refund of energy calculated G starting from the factors of intensity of the stresses by the formula of Irwin. Estimate

4.2.3 of the mistake made on the factors of intensity of the stresses In order to

evaluate the mistake made on the factors of intensity of the stresses in each node of the bottom, one evaluates the difference between the 6 values given by the 3 methods (see §4.19That gives an absolute deviation concerning, $K1$ (and $K2$ so $K3$ 3D). To obtain a relative variation easier to interpret, one standardizes the absolute deviations by a value which K is the maximum value of all in K this node of the crack tip.

More precisely, the mistake made on formula $K_i(i=1,2,3)$ being i the mode of request of crack and j the number of the method, is in the following way defined: ,

$$erreur(K_i) = \frac{\max_{j=1,2,3}(K_i^{j,MAX} - K_i^{j,MIN})}{K} \text{ with } K = \max_{j=1,2,3}(K_I^{j,MAX}, K_{II}^{j,MAX}, K_{III}^{j,MAX})$$

the errors on, $K1$ (and $K2$ so $K3$ 3D) are printed in the array: ERR _K1, ERR _K2 (and ERR _K3 if 3D) for each node of the crack tip. Additional

4.3 printings If

INFO is worth 2, all intermediate computations are displayed in the message file. It is announced that column entitled SAUT _DX (resp . SAUT _DY and SAUT _DZ) in the tables of the message file corresponds to the jump of displacement following the axis (respectively $X1$ and $X2$), $X3$ multiplied by a coefficient depend on the material, the whole with the square [R7.02.08]. Precautions

4.4 and advice

the assumptions necessary to the validity of this method are:

1) the crack must be sufficiently regular (either the bottom and the lips do not present a geometrical singularity);
2) the behavior must be elastic, linear, isotropic and homogeneous;
3) the structure must be isothermal (or, has minimum, the variations in temperature on the lips can be neglected in the zone of interpolation).

The method used is theoretically less precise and more sensitive to the mesh than the method of singular displacements [R7.02.05]. In a general way, one can advise to compare in the studies the results of POST _K1_K2_K3 and those of CALC_G [U 4.82.03], which is a good indicator of the quality of result obtained. The Councils

in the case fissures with a grid: the mesh must be preferably quadratic and comprise sufficient nodes perpendicular to the crack tip. In addition, the results are clearly improved if, if the mesh is composed of quadratic elements, one moves nodes mediums (edges which touch the crack tip), with the quarter of these edges by bringing them closer to the crack tip. This is made possible by key word MODI_MAILLE (option "NOEUD_QUART ") of the command MODI _MAILLAGE [U 4.23.04]. The computation

by interpolation of the jumps of displacement requires to have at least 3 nodes on the norm with the crack tip. If the number of nodes is not sufficient, an alarm is emitted and the lines corresponding to this node of the bottom are put at 0 in the table result. The computation continues then, if necessary, for the following node of the crack tip. One can in this case: that is to say

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- to increase maximum curvilinear X-coordinate the ABSC_CURV_MAXI to go to seek nodes further away from the crack tip; that is to say
- to increase parameter PREC_VIS_A_VIS (and possibly PREC_NORM in DEFI _FOND_FISS), which comes down to being less demanding in the selection of the nodes for computation. The Councils

in the case fissures nonwith a grid: the accuracy of the method is sensitive to the choice of the zone of enrichment of the method X-FEM (parameter RAYON_ENRI of DEFI_FISS_XFEM). In the ideal, the radius of enrichment and maximum curvilinear X-coordinate the ABSC_CURV_MAXI are about three times the size of the minimal edge of the mesh.

Computations are possible on a nonplane crack, but the user must take care that it remains sufficiently regular so that the design assumptions are valid: one should not have a geometrical singularity on the bottom or the lips. Typically, computation is licit for an axisymmetric crack, but not for a corner. The computation

by interpolation of the jumps of displacement requires to have at least 3 nodes on the norm with the crack tip. The number of points of interpolation is normally equal to NB_NOEUD_COUPE but can be lower in a case: if

> •the geometry of the bottom and structure is such as part of the points of interpolation leaves the matter. It is necessary in this case to reduce ABSC_CURV_MAXI (while remaining coherent with the smoothness of the mesh) and/or to increase NB_NOEUD_COUPE .

Computations are rather consuming in time and memory if there are many points on the crack tip. The use of key word NB_POINT_FOND makes it possible to limit postprocessing to a certain number of points équi-distribute along the bottom (for example about twenty points is often sufficient). Example

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5   1: structured mesh Fissures

circular in a block 3D (test SSLV134D). MY

```
=    LIRE_MAILLAGE () LEVINF
```

1, LEVINFS are the groups containing the meshes surface ones located on the upper lips and lower
of crack. The associated nodes groups are created: MY

```
= DEFI_GROUP (MAILLAGE     = MY, CREA_GROUP_NO
                =_F (GROUP_MA= ("LEVINF 1", "
                                        LEVINFS ", ))
Displacement
```

of the nodes to the quarter of the edges: MY

```
=    MODI_MAILLAGE (MAILLAGE = MY, reuse  = MY, MODI_MAILLE
                        =_F (OPTION= "        NOEUD_QUART", GROUP
                                    _MA_FOND= " LFF1",))
                        Computation
```

with MECA_STATIQUE … FISS

```
= DEFI_FOND_FISS (MAILLAGE = MY, FOND_FISS
                        = _F (        GROUP_MA= "          LFF1", GROUP
                                            _NO_ORIG= "      NFF1",
GROUP_NO_EXTR
                                    = "NFF2",),
                                LIP
                        _SUP= _F    (GROUP_MA = "LEVINFS"), LIP
                        _INF= _F    (GROUP_MA = "LEVINF1"), DTAN
                        _ORIG=      (   1.  , 0. , 0. ), DTAN
                        _EXTR=      (   0.  , 1. , 0. ) PREC
                        _NORM= 0.1  ,)
                    TABK

1K3 = POST_K1_K2_K3 (MODELISATION=   "    3D", INFO=2, BOTTOM
                        _FISS= FISS          , MATER
                        = MAT             , RESULTAT
                        = RESU1           , ABSC
                        _CURV_MAXI= 0.539   , PREC
                        _VIS_A_VIS= 0.1 ,)
                    Example
```

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6   2: free mesh In

3D, if the mesh is not regulated in crack tip, it can not there not have sufficient nodes on normal directions at the bottom for the interpolation. In this case, one must use option TYPE _MAILLAGE=' LIBRE'. With

this option, the principle of computation is the following determination

[1]   of the normal directions at the crack tip for each node of the bottom, definition

[2]   on each one of these directions of NB_NOEUD_COUPE points , équi-distribute between the bottom and distance ABSC_CURV_MAXI , projection

[3]   of the displacement of each lip on these nodes and interpolation of the jump of displacement.

Option TYPE _MAILLAGE=' LIBRE' is not available in 2D. The only case where that could be useful is the case of the nodes not coïncidents between the two lips. ABSC_CURV_MAXI
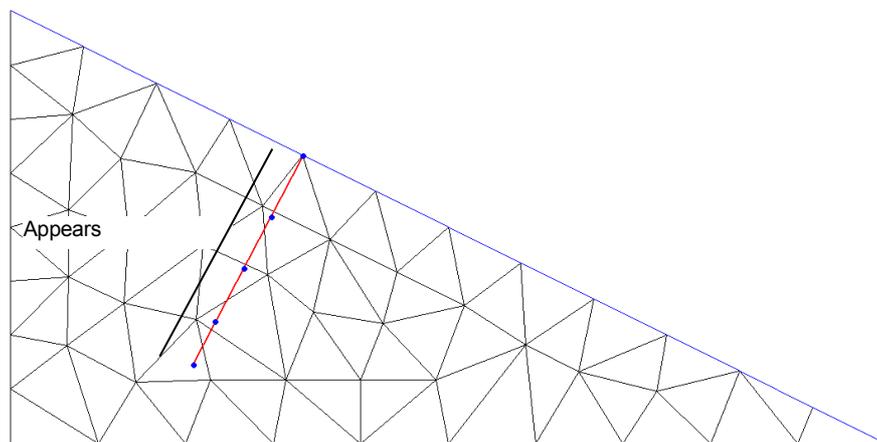
6a: Free mesh of the lips of crack – Definition of the points of projection TABK

```
= POST_K1_K2_K3 (MODELISATION=    "    3D", INFO=2, TYPE
                _MAILLAGE= "    LIBRE", _FISS=
                FISS,         MATER MELTS
                = MAT          , RESULTAT
                = RESU_MECA        , ABSC
                _CURV_MAXI= 0.539   , NB
                _NOEUD_COUPE= 5 ,)
```