

## Operator POST\_K1\_K2\_K3

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### 1 Goal

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To calculate the factors of intensity of the constraints in 2D and 3D.

This operator allows to calculate  $K1$ ,  $K2$  in 2D (plan and axisymmetric) and  $K3$  in 3D by extrapolation of the jumps of displacements on the lips of the crack, cf [R7.02.08]. This method is applicable only for 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 grid than calculation starting from the form bilinear of the rate of refund of energy and singular displacements, usable in 2D and 3D with the option `CALC_K_G` of the operator `CALC_G` [U4.82.03]. It however makes it possible to easily obtain a good estimate of the factors of intensity of the constraints.

Product a concept of the type `table`.

## 2 Syntax

```

tk [table] = POST_K1_K2_K3 (
    ♦ MODELING          = / '3D',
                        / 'AXIS',
                        / 'D_PLAN',
                        / 'C_PLAN',

    ♦ MATER             = chechmate ,
[material]

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

# 1) If FOND_FISS is indicated:

    ♦ RESULT           = resu,                / [evol_elas]
                                                / [evol_noli]
                                                / [mode_meca]

    ♦ / ALL             = 'YES',
    / | NODE            = noeu,                [l_noeud]
    / | GROUP_NO        = gr_noeu,            [l_gr_noeud]
    / | SANS_NOEUD      = noeu,                [l_noeud]
    / | SANS_GROUP_NO   = gr_noeu,            [l_gr_noeud]

# If modeling 3D
    ♦ TYPE_MALLAGE      = / 'RULE',            [DEFECT]
                        / 'FREE',

# Finsi
    ♦ NB_NOEUD_COUPE    = / 5,
                        / N,                [I]
    ♦ PREC_VIS_A_VIS    = / 1.E-1,            [DEFECT]
                        / epsi,              [R]
    ♦ EVOL_THER          = resuth,            [evol_ther]

# 2) If CRACK is indicated:

    ♦ RESULT           = resu,                / [evol_elas]
                                                / [evol_noli]
    ♦ NB_NOEUD_COUPE    = / 5,                [DEFECT]
                        / N,                [I]
    ♦ NB_POINT_FOND     = / nbnofo,           [I]
    ♦ NUME_FOND          = / 1,                [DEFECT]
                        / numfon,           [I]

# 3) END

    ♦ / TOUT_ORDRE      = 'YES',
    / NUME_ORDRE        = lnuor,                [L_I]
    / LIST_ORDRE        = lnuor,                [listis]

    / TOUT_MODE         = 'YES',
    / 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]
  ◊ CRITERION = / 'RELATIVE', [DEFECT]
                ◊ PRECISION = / prec, [R]
                                / 1.E-6, [DEFECT]
                / 'ABSOLUTE',
                ◆ PRECISION = prec, [R]
/
◊ TITLE = title, [l_Kn]
◊ INFORMATION = / 1,
)

```

## 3 Operands

### 3.1 Operand MODELING

```

♦ MODELING = / '3D',
              / 'AXIS',
              / 'D_PLAN',
              / 'C_PLAN',
    
```

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

### 3.2 Operand MATER

```

♦ MATER = chechmate , [material]
    
```

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

- if the operand `EVOL_THER` is not informed, then the characteristic materials are obtained at the temperature of reference `TEMP_DEF_ALPHA` of `DEFI_MATERIAU`;
- if the operand `EVOL_THER` is informed, then the characteristic materials are calculated starting from the temperature of the nodes of the bottom of crack.

### 3.3 Case where the operand FOND\_FISS is well informed

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

#### 3.3.1 Operands

```

FOND_FISS /
PREC_VIS_A_VIS/NODE/GROUP_NO/SANS_NOEUD/SANS_GROUP_NO
    
```

```

♦ FOND_FISS = bottom, [fond_fiss]
♦ PREC_VIS_A_VIS = / 1.D-1, [DEFECT]
                  / epsi, [R]
♦ / ALL = 'YES',
  / | NODE = noeu, [l_noeud]
  / | GROUP_NO = gr_noeu, [l_gr_noeud]
  / | SANS_NOEUD = noeu, [l_noeud]
  / | SANS_GROUP_NO = gr_noeu, [l_gr_noeud]
    
```

The operand `FOND_FISS` allows to provide the concept `fond_fiss` (created by the order `DEFI_FOND_FISS`) in which the necessary information are stored with the automatic research of the nodes of the two lips located on normal segments at the bottom of crack. Attention, the concept `fond_fiss` must necessarily be defined such as the lips of the crack are initially stuck (`CONFIG_INIT='COLLEE'` in `DEFI_FOND_FISS` [U4.82.01])

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

- to select certain nodes tops of the bottom of crack (keywords `NODE` and `GROUP_NO`);
- to exclude from the nodes of the bottom of crack (keywords `SANS_NOEUD` and `SANS_GROUP_NO`);
- to calculate on all the nodes mediums and tops of the bottom of crack (keyword `ALL`).

◇ `ABSC_CURV_MAXI = dmax [R]`

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

The 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* sizes of the meshes connected to the nodes of the bottom of crack. These sizes of meshes in each node of the bottom are calculated in the order `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 the structure.

At the time of automatic research for each node of the bottom of crack, the operator selects the nodes checking the following conditions:

- distance *R* compared to the bottom of crack:  $R < \text{ABSC\_CURV\_MAXI}$ ,
- distance *L* compared to its opposite on the other lip:  
 $L < \text{epsi} \cdot \text{ABSC\_CURV\_MAXI}$ ,
- and in 3D outdistances *D* of a node of the lips to the right-hand side perpendicular to the bottom of crack:  $D < \text{epsi\_fond} \cdot d$ , where *d* is the minimal distance between two successive nodes of the bottom of crack, where `epsi` of the provided precision (keyword is the value `PREC_VIS_A_VIS`) and `epsi_fond` the value of the precision provided in the keyword `PREC_NORM` of `DEFI_FOND_FISS`.

By default `epsi` is worth `0,1`. To increase the value of `PREC_VIS_A_VIS` (and/or of `PREC_NORM` in `DEFI_FOND_FISS`) come down to increase the number of nodes potentially retained for calculation.

#### Notice :

*If `TYPE_MALLAGE= 'REGLE'`, this precision intervenes in the phase of projection of the result on the line of cut: a point is regarded as being out of the matter if its distance to the structure is higher than  $\text{epsi} \cdot \text{ABSC\_CURV\_MAXI}$ . 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 RESULT

- ◆ RESULT = resu,

resu is a concept of the type evol\_elas, evol\_noli or mode\_meca containing the field of displacement on all the model.

**Notice :**

*resu cannot be a concept of the type mode\_meca that if TYPE\_MAILLAGE='REGLE'.*

## 3.3.3 Operand TYPE\_MAILLAGE

- ◇ TYPE\_MAILLAGE = / 'RULE', [defect]  
/ 'FREE',

This keyword is available only in 3D, for the cracks with a grid defined by FOND\_FISS.

If TYPE\_MAILLAGE= 'REGULATES', option to use by default, calculation is done by supposing that the nodes on the lips of the crack are on normal directions at the bottom and exactly in with respect to a lip with the other. Messages of alarm or error are transmitted if it is not the case.

If the grid does not meet these conditions, one can use the option TYPE\_MAILLAGE='LIBRE'. The principle of calculation is then the following:

1. determination of the normal directions at the bottom of crack 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.

Calculation with TYPE\_MAILLAGE=' LIBRE ' can be less precise than calculation by default.

## 3.3.4 Operand NB\_NOEUD\_COUPE

- ◇ NB\_NOEUD\_COUPE= / 5, [DEFECT]  
/ N, [I]

This operand intervenes only if TYPE\_MAILLAGE= 'LIBRE' is well informed. 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 bottom of crack and the distance ABSC\_CURV\_MAXI.

**Notice :**

*The projection of the displacement of the lips on 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 well informed

This case corresponds to a calculation on a crack nonwith a grid, definite for calculation then for postprocessing with the operator DEFI\_FISS\_XFEM.

### 3.4.1 Operand CRACK

*Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.*

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- ◆ CRACK = fiss,

Concept of the type `fiss_xfem`, product by the order `DEFI_FISS_XFEM`.

### 3.4.2 Operand RESULT

- ◆ RESULT = resu,

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

### 3.4.3 Operand ABSC\_CURV\_MAXI

- ◇ ABSC\_CURV\_MAXI = dmax [R]

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

The 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* sizes of the meshes connected to the nodes of the bottom of crack. These sizes of meshes in each node of the bottom are calculated in the order `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 the structure.

### 3.4.4 Operand NUME\_FOND

- ◇ NUME\_FOND = / 1, [DEFECT]  
/ numfon, [I]

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

### 3.4.5 Operand NB\_NOEUD\_COUPE

- ◇ NB\_NOEUD\_COUPE = / 5, [DEFECT]  
/ 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 bottom of crack and the distance `ABSC_CURV_MAXI`.

### 3.4.6 Operand NB\_POINT\_FOND

- ◇ NB\_POINT\_FOND = / nbnofo, [I]

By default for a crack X-FEM, calculation is done on all the points of the bottom of crack, i.e all the points of intersection between the bottom of crack and the edges of the grid. The operand `NB_POINT_FOND` allows to fix *a priori* the number of points of postprocessing, in order to limit the computing times. `nbnofo` points are équi-distribute along the bottom of crack.

### 3.5 Operands `INST`, `LIST_INST`, `FREQ`, `LIST_FREQ`, `TOUT_ORDRE`, `NUME_ORDRE`, `LIST_ORDRE`, `TOUT_MODE`, `NUME_MODE`, `LIST_MODE`

Cf [U4.71.00].

### 3.6 Operand `INFORMATION`

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

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

### 3.7 Operand `TITLE`

◇ `TITLE = title,`

Title which one wants to give to the result of the order.

## 4 Precautions and advices of use

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

In each node of the bottom of crack, one uses 3 methods (alternatives) to determine  $K_I$ ,  $K_{II}$  (and  $K_{III}$  in 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 by  $r$ . Various values of  $K_I$  (resp.  $K_2$ ,  $K_3$ ) are obtained (except for a multiplicative factor) by extrapolation in  $r=0$  segments of right-hand sides thus obtained.
- Method 2: one traces the jump of the field of displacements squared according to  $r$ . Approximations of  $K_I$  are (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 bottom of crack, each method provides a value MAX and a value MIN. In each node of the bottom of crack, one thus has 6 values for  $K_I$ , 6 values for  $K_{II}$  and 6 values for  $K_{III}$  (for method 3, min and max values coincide). One notes these values as follows, the exhibitor  $j$  corresponding to the number of the method:

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

### 4.2 Produced table

The order POST\_K1\_K2\_K3 product a concept of the type table. The table can be printed by IMPR\_TABLE [U4.91.03]. It contains for each node of the bottom of crack:

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

The following paragraphs detail these sizes.

#### 4.2.1 Values of the factors of intensity of the constraints

The produced table contains, for each node (or not) of the bottom of crack, the values of the stress intensity factors corresponding to the values MAX of the method n°1 (see §4.1):

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

$$\text{In 3D, one has moreover } K3 ( = K_{III}^{1,MAX})$$

One is thus printedE only value of  $K_I$ ,  $K_2$  (and  $K_3$  if 3D) prear node of the bottom of crack.

#### 4.2.2 Values of the rate of refund of energy

The produced table contains, for each node (or not) of the bottom of crack, the value of the rate of refund of energy  $G$  calculated starting from the factors of intensity of the constraints by the formula of Irwin.

## 4.2.3 Estimate of the mistake made on the factors of intensity of the constraints

In order to evaluate the mistake made on the factors of intensity of the constraints in each node of the bottom, one evaluates the difference between the 6 values given by the 3 methods (see §4.1). That gives an absolute deviation concerning  $K_I$ ,  $K_2$  (and  $K_3$  if 3D). To obtain a relative variation easier to interpret, one standardizes the absolute deviations by a value  $K$  who is the maximum value of all them  $K$  in this node of the bottom of crack.

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

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

Erreurs on  $K_I$ ,  $K_2$  (and  $K_3$  if 3D) sound printed in the table: ERR\_K1, ERR\_K2 (and ERR\_K3 if 3D) for each node of the bottom of crack.

## 4.3 Additional impressions

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

## 4.4 Precautions and advices

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 grid 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 [U4.82.03], which is a good indicator of the quality of the got result.

**The Councils in the case fissures with a grid:** the grid must be preferably quadratic and comprise sufficient nodes perpendicular to the bottom of crack. In addition, the results are clearly improved if, if the grid is composed of quadratic elements, one moves nodes mediums (edges which touch the bottom of crack), with the quarter of these edges by bringing closer them to the bottom to crack. This is made possible by the keyword MODI\_MAILLE (option 'NOEUD\_QUART') order MODI\_MAILLAGE [U4.23.04].

Calculation by interpolation of the jumps of displacement requires to have at least 3 nodes on the normal at the bottom of crack. 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 table result. Calculation continues then, if necessary, for the following node of the bottom of crack. One can in this case:

- that is to say to increase the maximum curvilinear X-coordinate ABSC\_CURV\_MAXI to go to seek nodes further away from the bottom of crack;

- that is to say to increase the 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 calculation.

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

Calculations 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, calculation is licit for an axisymmetric crack, but not for a corner.

Calculation by interpolation jumps of displacement requires to have at least 3 nodes on the normal at the bottom of crack. 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 the 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 grid) and/or to increase `NB_NOEUD_COUPE`.

Calculations are rather consuming in time and memory if there are many points on the bottom of crack. The use of the keyword `NB_POINT_FOND` allows to limit postprocessing to a certain number of points équi-distribute along the bottom (for example about twenty points is often sufficient).

## 5 Example 1: regulated grid

Circular crack in a block 3D (test SSLV134D).

```
MY = LIRE_MALLAGE ( )
```

LEVINF1, LEVINFS are the groups containing the surface meshes located on the upper lips and lower of the crack. One creates the groups of associated nodes:

```
MY = DEFI_GROUP ( GRID = MY,  
                  CREA_GROUP_NO = _F (GROUP_MA= ( ' LEVINFS ',  
                                                  ' LEVINFS ',))
```

Displacement of the nodes to the quarter of the edges:

```
MY = MODI_MALLAGE (GRID = MY, reuse = MY,  
                  MODI_MAILLE = _F (OPTION = 'NOEUD_QUART',  
                                     GROUP_MA_FOND = 'LFF1',)  
                  )
```

Calculation with MECA\_STATIQUE...

```
FISS = DEFI_FOND_FISS (GRID = MY,  
                      FOND_FISS = _F ( GROUP_MA = 'LFF1',  
                                       GROUP_NO_ORIG = 'NFF1',  
                                       GROUP_NO_EXTR = 'NFF2',  
                                       ),  
                      LEVRE_SUP = _F (GROUP_MA = 'LEVINFS'),  
                      LEVRE_INF = _F (GROUP_MA = 'LEVINF1'),  
                      DTAN_ORIG = ( 1. , 0. , 0. ),  
                      DTAN_EXTR = ( 0. , 1. , 0. ),  
                      PREC_NORM = 0.1,  
                      )
```

```
TABK1K3 = POST_K1_K2_K3 ( MODELING = '3D', INFO=2,  
                          FOND_FISS = FISS,  
                          MATER = CHECHMATE,  
                          RESULT = RESU1,  
                          ABSC_CURV_MAXI = 0,539,  
                          PREC_VIS_A_VIS = 0.1,  
                          )
```

## 6 Example 2: free grid

In 3D, if the grid is not regulated in bottom of crack, there can not be sufficient nodes on normal directions at the bottom for the interpolation. In this case, one must use the option `TYPE_MALLAGE=' LIBRE '`.

With this option, the principle of calculation is the following

- [1] determination of the normal directions at the bottom of crack 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 and interpolation of the jump of displacement.

The option `TYPE_MALLAGE=' LIBRE '` is not available in 2D. The only case where that could be useful is the case of the nodes not coincidents between the two lips.

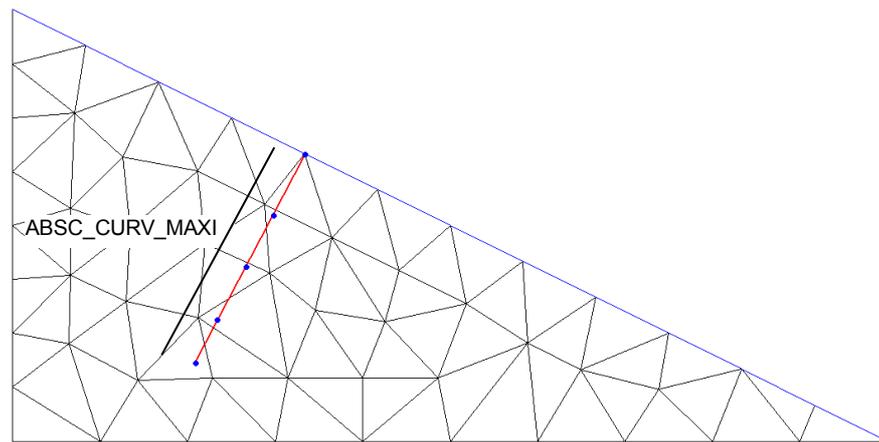


Figure 6a: Free grid of the lips of the crack – Definition of the points of projection

```
TABK = POST_K1_K2_K3 ( MODELING      = '3D', INFO=2,  
                      TYPE_MALLAGE  = 'FREE',  
                      FOND_FISS      = FISS,  
                      MATER          = CHECHMATE,  
                      RESULT         = RESU_MECA,  
                      ABSC_CURV_MAXI = 0,539,  
                      NB_NOEUD_COUPE = 5,  
                      )
```