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## Operator POST\_RUPTURE

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### 1 Goal

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To carry out postprocessings of the tables of results resulting from the operators `CALC_G` and `POST_K1_K2_K3`.

The various possible operations are:

- standardisation of the curvilinear X-coordinate,
- calculation of the angle of junction,
- counting of the cycles in fatigue,
- calculation of the increment of advanced of fatigue crack,
- office plurality of the cycles in fatigue,
- piloting of the propagation,
- calculation of stress intensity factor are equivalent,
- calculation of  $(\Delta K)_{eq}$  used for the propagation in variable amplitude,
- zero setting of the negative values of the stress intensity factors  $K_1$  and calculation of the new rates of refund  $G$  and/or  $G_{IRWIN}$  by the formula of Irwin.

Product a structure of data `table`.

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## 2 Syntax

```
postrupt [table] = POST_RUPTURE (  
  
♦ TABLE = , [table]  
  
♦ OPERATION = / 'ABSC_CURV_NORM' ,  
/ 'ANGLE_BIFURCATION' ,  
/ 'LOI_PROPA'  
/ 'COMPTAGE_CYCLES'  
/ 'CUMUL_CYCLES'  
/ 'PILO_PROPA'  
/ 'K1_NEGATIF'  
  
# if OPERATION = 'ABSC_CURV_NORM'  
◇ NOM_PARA = / 'ABSC_CURV_NORM' [DEFECT]  
/ will nom_para, [TXT]  
  
# if OPERATION = 'ANGLE_BIFURCATION'  
◇ NOM_PARA = / 'BETA' [DEFECT]  
/ nom_angle, [TXT]  
◇ CRITERION = / 'SITT_MAX' [DEFECT]  
/ 'SITT_MAX_DEVER'  
/ 'K1_MAX',  
/ 'K2_NUL',  
/ 'PLAN',  
  
# if OPERATION = 'K_EQ'  
◇ NOM_PARA = / 'K_EQ' [DEFECT]  
/ nom_cumul, [TXT]  
◇ OFFICE PLURALITY = / 'CUMUL_G', [DEFECT]  
/ 'LINEAR',  
/ 'QUADRATIC',  
/ 'MODE_I',  
  
# if OPERATION = 'DELTA_K_EQ'  
◇ NOM_PARA = / 'DELTA_K_EQ' [DEFECT]  
/ nom_cumul, [TXT]  
◇ OFFICE PLURALITY = / 'CUMUL_G', [DEFECT]  
/ 'QUADRATIC',  
/ 'MODE_I',  
  
# if OPERATION = 'COMPTAGE_CYCLES'  
♦ NOM_PARA = / will nom_para, [TXT]  
♦ COUNTING = / 'RAINFLOW',  
/ 'RCCM',  
/ 'NATURAL',  
/ 'UNIT'  
◇ DELTA_OSCI = / 0. [DEFECT]  
/ delta, [R]  
# if COUNTING = 'UNIT'  
♦ COEF_MULT_MINI = cmini [R]  
♦ COEF_MULT_MAXI = cmaxi [R]  
  
# if OPERATION = 'LOI_PROPA'  
◇ NOM_PARA = / 'DELTA_A' [DEFECT]
```

```

    / nom_da, [TXT]
◇ NOM_DELTA_K_EQ = / ' DELTA_K_EQ ' [DEFECT]
    / nom_dkeq [TXT]
◆ / LAW = / 'PARIS' [DEFECT]
  / C = C, [R]
  / M = M, [R]
◇ DELTA_K_SEUIL= / 0. , [DEFECT]
    / val_seuil , [R]
)

# if OPERATION = 'CUMUL_CYCLES'
◇ NOM_PARA = / 'DELTA_A' [DEFECT]
    / nom_da, [TXT]
◇ OFFICE PLURALITY = 'LINEAR' [DEFECT]

# if OPERATION = 'PILO_PROPA'
◆ / DELTA_A_MAX = da, [R]
  / DELTA_N = dn, [R]

# if OPERATION = 'K1_NEGATIF'
◆ MODELING = / '3D'
    / 'C_PLAN'
    / 'D_PLAN'
    / 'AXIS'
◆ MATER = chechmate, [material]
```

## 3 Opérandes

### 3.1 Generic operands

#### 3.1.1 Operand TABLE

◆ TABLE = , [table]

Cand operand makes it possible to choose the table on which one carries out the operations. This table comes in order CALC\_G, that is to say order POST\_K1\_K2\_K3.

#### 3.1.2 Operand OPERATION

◆ OPERATION = / 'ABSC\_CURV\_NORM',  
/ 'ANGLE\_BIFURCATION',  
/ 'LOI\_PROPA'

Cand operand makes it possible to choose the operation to be carried out.  
For an explanation of the various operations, to see the corresponding paragraphs below.

### 3.2 Operands for the operation 'ABSC\_CURV\_NORM'

The operation 'ABSC\_CURV\_NORM' create a new column in the table at exit, corresponding to the curvilinear X-coordinate normalized along the bottom of crack. For that, it is necessary that the table as starter contains a column 'ABSC\_CURV'. The table as starter can comprise several funds of crack. It can contain one or more moments for each fund of crack.

#### 3.2.1 Operand NOM\_PARA

◇ NOM\_PARA = / 'ABSC\_CURV\_NORM' [DEFECT]  
/ will nom\_para, [TXT]

This operand makes it possible to choose the name of the new column created.

### 3.3 Operands for the operation 'ANGLE\_BIFURCATION'

The operation 'ANGLE\_BIFURCATION' create a new column in the table at exit, corresponding to the angle of junction of the crack who is given in degree. The table as starter can comprise several funds of crack. It can contain one or more moments for each fund of crack.

#### 3.3.1 Operand NOM\_PARA

◇ NOM\_PARA = / 'BETA' [DEFECT]  
/ nom\_angle, [TXT]

This operand makes it possible to choose the name of the new column created.

#### 3.3.2 Operand CRITERION

◇ CRITERION = / 'SITT\_MAX' [DEFECT]  
/ 'SITT\_MAX\_DEVER'  
/ 'K1\_MAX',  
/ 'K2\_NUL',

/ 'PLAN' ,

This operand makes it possible to choose the criterion of calculation of the angle of junction:

- 'SITT\_MAX' : criterion of the maximum circumferential constraint (Maximum Hoop Stress criterion, [R7.02.05 §2.5.2]) it is the by default criterion. It is calculated starting from the values of  $K1$  and  $K2$ . It is available in 2D and 3D.
- 'SITT\_MAX\_DEVER' : criterion of the maximum circumferential constraint (Maximum Hoop Stress criterion, [R7.02.13 §2.1]) with taking into account of mode III and calculation of the dumping angle.
- 'K1\_MAX' , 'K2\_NUL' : criteria of Amestoy, Bui and Dang-Van [R7.02.05 §2.5.1]. These 2 criteria are only available in 2D. The angle is given with a margin of 10 degrees.

Attention, one notes that the criterion 'K2\_NUL' do not function for an angle higher than  $60^\circ$ .

- 'PLAN' : defines a null angle.

## 3.4 Operands for the operation 'K\_EQ'

The operation 'K\_EQ' create a new column in the table at exit, corresponding to the office plurality of the modes. It can contain one or more moments, but the Young modulus and the Poisson's ratio in the case of office plurality of the type 'CUMUL\_G' or 'QUADRATIC' must be definite constant in time.

### 3.4.1 Operand NOM\_PARA

◇ NOM\_PARA = / 'K\_EQ' [DEFECT]  
/ nom\_cumul, [TXT]

This operand makes it possible to choose the name of the new column created.

### 3.4.2 Operand OFFICE\_PLURALITY

◇ OFFICE\_PLURALITY = / 'CUMUL\_G' [DEFECT]  
/ 'QUADRATIC',  
/ 'LINEAR',  
/ 'MODE\_I',

This operand makes it possible to choose the rule of office plurality of the mode:

- 'CUMUL\_G' : it is the office plurality by default. It is calculated starting from the rate of refund of energy  $G$  values of the Young modulus  $E$  and of the Poisson's ratio  $\nu$ . It is available in 2D and 3D.

$$\sqrt{\frac{G E}{1-\nu^2}}$$

- 'QUADRATIC' : This office plurality is calculated starting from the values of the Poisson's ratio  $\nu$ . It is available in 2D and 3D.

In 2D, this office plurality is written:

$$\sqrt{K1^2 + K2^2}$$

In 3D, this office plurality is written:

$$\sqrt{K1^2 + K2^2 + \frac{K3^2}{1-\nu}}$$

- `'LINEAR'` :  
In 2D, this office plurality is written:

$$\max(K1,0)+|K2|$$

In 3D, this office plurality is written:

$$\max(K1,0)+|K2|+0,74|K3|$$

- `'MODE_I'` : This office plurality is available in 2D and in 3D and is written:

$$K1$$

## 3.5 Operands for the operation `'DELTA_K_EQ'`

The operation `'DELTA_K_EQ'` create a new column in the table at exit, corresponding to the office plurality of the modes. It can contain one or more moments, but the Young modulus and the Poisson's ratio in the case of office plurality of the type `'CUMUL_G'` or `'QUADRATIC'` must be definite constant in time.

### 3.5.1 Operand `NOM_PARA`

$$\diamond \quad \text{NOM\_PARA} = \begin{array}{l} / \quad \text{'DELTA\_K\_EQ'} \\ / \quad \text{nom\_cumul,} \end{array} \quad \begin{array}{l} [\text{DEFECT}] \\ [\text{TXT}] \end{array}$$

This operand makes it possible to choose the name of the new column created.

### 3.5.2 Operand `OFFICE_PLURALITY`

$$\diamond \quad \text{OFFICE\_PLURALITY} = \begin{array}{l} / \quad \text{'CUMUL\_G'} \\ / \quad \text{'QUADRATIC'}, \\ / \quad \text{'MODE\_I'}, \end{array} \quad [\text{DEFECT}]$$

This operand makes it possible to choose the rule of office plurality of the mode:

- `'CUMUL_G'` : it is the office plurality by default. It is calculated starting from the rate of refund of energy  $G$  values of the Young modulus  $E$  and of the Poisson's ratio  $\nu$ . It is available in 2D and 3D.

$$\sqrt{\frac{G E}{1-\nu^2}}$$

- `'QUADRATIC'` : This office plurality is calculated starting from the values of the Poisson's ratio  $\nu$ . It is available in 2D and 3D.

In 2D, this office plurality is written:

$$\sqrt{\Delta K1^2 + \Delta K2^2}$$

In 3D, this office plurality is written:

$$\sqrt{\Delta K1^2 + \Delta K2^2 + \frac{\Delta K3^2}{1-\nu^2}}$$

- 'MODE\_I' : This office plurality is available in 2D and in 3D and is written:

$$\Delta KI$$

## 3.6 Operands for the operation 'COMPTAGE\_CYCLES'

The operation 'COMPTAGE\_CYCLES' allows to calculate the cycles related to the evolution of one (or several) quantity (S). This operation created a new table, with a column CYCLES and a column corresponding to the variation of the quantity counted to cycle. The table as starter can comprise several funds of crack.

### 3.6.1 Operand NOM\_PARA

◆ NOM\_PARA = / WILL NOM\_PARA , [TXT]

This operand makes it possible to choose the name of the quantity on which the counting of the cycles is carried out.

One can possibly carry out counting on several quantities (for example  $K1$  ,  $K2$  and  $K3$  ), provided one finds the same number of cycles for each quantity.

### 3.6.2 Operand COUNTING

◆ COUNTING = / 'RAINFLOW' ,  
/ 'RCCM' ,  
/ 'NATURAL' ,  
/ 'UNIT'

This operand makes it possible to choose the method counting of the cycles. Except for counting UNIT, one calls on the order POST\_FATIGUE. For more information on the methods of countings, to see documentation [R7.04.01]. The table as starter can contain one or more moments, but corresponding to the same bottom of crack.

Counting UNIT is a typical case for the linear elastic designs. In this case, the table as starter should contain one moment and the variation of the quantity will then be determined by the operands COEF\_MULT\_MINI and COEF\_MULT\_MAXI.

### 3.6.3 Operand DELTA\_OSCI

◆ DELTA\_OSCI = / 0. [DEFECT]  
/ DELTA, [R]

to see documentation [U4.83.01]

### 3.6.4 Operands COEF\_MULT\_MINI and COEF\_MULT\_MAXI

◆ COEF\_MULT\_MINI = cmini [R]  
◆ COEF\_MULT\_MAXI = cmaxi [R]

For unit counting, the variation of the quantity to be counted is the following one:

$$\Delta q = q_u (c_{maxi} - c_{mini})$$

where  $q$  is the quantity to be counted, and  $q_u$  the unit value of this quantity (only value contained in the table as starter).



## 3.7 Operands for the operation 'LOI\_PROPA'

The operation 'LOI\_PROPA' create a new column in the table at exit, corresponding to the unit projection (i.e. for a cycle) of a crack taking into account a law of propagation in fatigue. The table as starter can comprise several funds of crack. It can contain one or more moments for each fund of crack.

### 3.7.1 Operand NOM\_PARA

◇ NOM\_PARA = / 'DELTA\_A' [DEFECT]  
/ nom\_da, [TXT]

This operand makes it possible to choose the name of the new column created.

### 3.7.2 Operands LAW, C, M, NOM\_DELTA\_K\_EQ

◆ / LAW = / 'PARIS' [DEFECT]  
/ C = C, [R]  
/ M = M, [R]  
◇ DELTA\_K\_SEUIL = / 0. [DEFECT]  
/ val\_seuil, [R]  
  
◇ NOM\_DELTA\_K\_EQ = / ' DELTA\_K\_EQ ' [DEFECT]  
/ nom\_dkeq [TXT]

The operand LAW allows to specify the law of propagation in fatigue selected. For the moment, only the law of Paris is available. This law is written:

$$\frac{da}{dN} = C.(\Delta K_{eq} - \Delta K_{seuil})^m$$

where  $C$  and  $m$  are coefficients materials, indicated by the operands C and M.  $\Delta K_{seuil}$  is the threshold of propagation, adjustable by the optional parameter DELTA\_K\_SEUIL, whose value by default is of 0. If  $\Delta K_{eq} \leq \Delta K_{seuil}$ , then the projection is worthless.

The column in the table of entry corresponding to  $\Delta K_{eq}$  is specified by the operand NOM\_DELTA\_K\_EQ.

One calculates the unit projection then ( $\Delta N = 1$  implicitly):

$$\Delta a = C.(\Delta K_{eq} - \Delta K_{seuil})^m$$

Note:

In mode I pure:  $\Delta K_{eq}$  is worth  $\Delta K_I$ . In mixed mode,  $\Delta K_{eq}$  can be written  $(\Delta K)_{eq}$  or  $\Delta(K_{eq})$ , according to the conventions. These two quantities are generally different. There exist however cases where these two quantities are identical:

- in pure mode 1 if  $KI$  is always positive,
- in mixed mode into linear for a cycle (0-max).

## 3.8 Operands for the operation 'CUMUL\_CYCLES'

The operation 'CUMUL\_CYCLES' allows to cumulate a quantity previously counted for each cycle by calculating the average on all the cycles. The table created contains all the initial columns of the table, except the column CYCLE. Attention, in a point of the bottom, it is necessary that the other columns of the table do not vary during cycles. The name of the column corresponding to the quantity with office plurality does not change.

The table as starter can comprise several funds of crack.

## 3.8.1 Operand NOM\_PARA

◇ NOM\_PARA = / 'DELTA\_A' [DEFECT]  
/ nom\_da, [TXT]

This operand makes it possible to specify the name of the parameter on which the office plurality is carried out. By default, one carries out the office plurality on 'DELTA\_A'.

## 3.8.2 Operand OFFICE\_PLURALITY

◇ OFFICE\_PLURALITY = 'LINEAR' [DEFECT]

This operand is not useful for the moment, because the only authorized office plurality is the linear office plurality (arithmetic mean on the cycles):

$$q_{cumul} = \frac{1}{N} \sum_{i=1}^N q_i$$

where  $q_i$  corresponds to the value for cycle  $i$  quantity to be cumulated.

## 3.9 Operands for the operation 'PILO\_PROPA'

The operation 'PILO\_PROPA' allows to control the propagation of several funds of crack (for the moment, limited to only one fissures). Piloting is done :

- maybe by imposing the increment amongst cycles (piloting in cycles);
- maybe out of Imposant the increment of maximum projection of the bottom of crack (piloting into advanced).

This piloting takes account of all the points of all the funds of all the cracks.

The table as starter must contain the parameter DELTA\_A.

### 3.9.1 Operands DELTA\_A\_MAX and DELTA\_N

◆ / DELTA\_A\_MAX = da, [R]  
/ DELTA\_N = dn, [R]

To control the propagation in cycles, one uses DELTA\_N. That causes to multiply the value of the projection (unit) by a factor  $dn$  for all the points of all the funds of all the cracks.

The other mode of piloting consists in fixing the increment of maximum projection  $da$  via the operand DELTA\_A\_MAX. Initially, one determines the point of all the funds of all the cracks which has the highest projection. Let us note  $damax$  this projection. The number of cycles applied will be then

$$\frac{da}{damax}$$

## 3.10 Operands for the operation 'K1\_NEGATIF'

The operation 'K1\_NEGATIF' is to discuss the items of the bottom for which the stress intensity factor  $KI$  is negative.

For these points where values of  $KI$  are negative,  $KI$  is put at zero and the rates of refund  $G$  and/or  $G_{IRWIN}$  are recomputed by the formula of Irwin.

So at least one of the two rates of refund is present in the table as starter, the latter must also contain the parameter  $K2$  (and  $K3$  in 3D).

The table of entry can comprise several moments of calculation and several funds of crack.

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## 3.10.1 Operand MODELING

```
◆ MODELING = / `3D`  
/ `C_PLAN`  
/ `D_PLAN`  
/ `AXIS`
```

This operand makes it possible to choose the formula of Irwin adapted to the type of modeling employed.

When  $KI$  is null, the formula of Irwin is:

In 3D:

$$G = \frac{1-\nu^2}{E} K2^2 + \frac{1+\nu}{E} K3^2$$

In plane deformations and for the axisymetry according to the axis of  $Y$  :

$$G = \frac{1-\nu^2}{E} K2^2$$

In plane constraints:

$$G = \frac{K2^2}{E}$$

where  $E$  is the Young modulus and  $\nu$  Poisson's ratio.

## 3.10.2 Operand TO SUBDUE

```
◆ MATER = chechmate, [material]
```

This operand recovers the name of material used for calculations. The parameters material are then used in the formula of Irwin to recompute the rates of refund. The Young modulus and the Poisson's ratio must be definite constant in time.