Operator POST_RUPTURE

1 Drank

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

The various possible operations are:
•standardization of the curvilinear abscisse,
•computation of the angle of bifurcation,
•counting of the cycles in fatigue,
•computation of the increment of advanced of fatigue crack,
•office plurality of the cycles in fatigue,
•control of the propagation,
•computation of the stress intensity factor are equivalent,
•computation of $(\Delta K)_{eq}$ used for the propagation in variable amplitude,
•put at zero of the negative values of the stress intensity factors K_1 and computation of the new rates of refund G and/or G_{IRWIN} by the formula of Irwin.

Product a data structure counts.

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2 Syntax

```
postrupt [array] =POST_RUPTURE    (

♦TABLE        =  ,                                  [array]

♦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"            [DEFAULT]
                   /NOM_PARA ,                       [TXT]


# if OPERATION = "ANGLE_BIFURCATION"
◊   NOM_PARA    =       "BETA"                      [DEFAULT]
                   /NOM_ANGLE   ,                    [TXT]
◊   CRITERION   =       "SITT_MAX"                    [DEFAULT]
                /  "K1_MAX",
                /  "K2_NUL",
                /  "PLANE",

# if OPERATION = "K_EQ"
◊   NOM_PARA    =       "K_EQ"                      [DEFAULT]
                   /NOM_CUMUL   ,                    [TXT]
◊   CUMUL    =       "CUMUL_G",                     [DEFAULT]
                   /  "LINEAIRE",
                   /  "QUADRATIQUE",
                   /  "MODE_I",

# if OPERATION = "DELTA_K_EQ"
◊   NOM_PARA    =       "DELTA_K_EQ"                  [DEFAULT]
                   /NOM_CUMUL   ,                    [TXT]
◊   CUMUL    =       "CUMUL_G",                     [DEFAULT]
                   /  "QUADRATIQUE",
                   /  "MODE_I",


# if OPERATION = "COMPTAGE_CYCLES"
♦   NOM_PARA    WILL =/NOM_PARA     ,                        [TXT]
♦   COMPTAGE    =       "RAINFLOW",
                   /  "RCCM",
                   /  "NATUREL",
                   /  "UNITAIRE"
◊   DELTA_OSCI=/0          .                          [DEFAULT]
                   /DELTA ,                          [R]
   # if COMPTAGE = "UNITAIRE"
   ♦   COEF_MULT_MINI=     cmini                     [R]
   ♦   COEF_MULT_MAXI=     cmaxi                     [R]


# if OPERATION = "LOI_PROPA"
◊   NOM_PARA           =       "DELTA_A"            [DEFAULT]
                       /NOM_DA   ,                   [TXT]
```

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```
◊   NOM_DELTA_K_EQ  =      " DELTA_K_EQ "              [DEFAULT]
                       /   nom_dkeq                     [TXT]
♦/LOI=/                          "PARIS"                      [DEFAULT]
   /C                =C ,                              [R]
   /M                =M ,                              [R]
                  )


# if OPERATION = "CUMUL_CYCLES"
◊   NOM_PARA    =       "DELTA_A"                      [DEFAULT]
                    /   nom_da,                        [TXT]
◊   CUMUL    =    ' LINEAR"                            [DEFAULT]


# if OPERATION = "PILO_PROPA"
♦   /DELTA_   A_MAX    =    da,                            [R]
   /   DELTA_N      =    dn,                             [R]

# if OPERATION = "K1_NEGATIF"
♦   MODELISATION    =       "3D"
                       /   "C_PLAN"
                       /   "D_PLAN"
                       /    "AXIS"
♦   MATER      = mat,                                [material]
```

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3 generic

3.1 Operands Operands

3.1.1 Operand COUNTS

```
♦TABLE=TAB                ,                                  [array]
```

THIS operand makes it possible to choose the array on which one carries out the operations. This array comes either of the command CALC_G, or of the command POST_K1_K2_K3.

3.1.2 Operand OPERATION

```
♦OPERATION=/              "ABSC_CURV_NORM",
                  /   "ANGLE_BIFURCATION",
                  /   "LOI_PROPA"
```

THIS 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 operation "ABSC_CURV_NORM"

operation "ABSC_CURV_NORM" creates a new column in the array in output, corresponding to the curvilinear abscisse normalized along the crack tip. For that, it is necessary that the array in entry contains a column "ABSC_CURV". The array as starter can comprise several crack tips . It can contain one or more times for each crack tip.

3.2.1 Operand NOM_PARA

```
◊   NOM_PARA     =       "ABSC_CURV_NORM"                    [DEFAULT]
                       /NOM_PARA ,                           [TXT]
```

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

3.3 Operands for operation "ANGLE_BIFURCATION"

operation "ANGLE_BIFURCATION" creates a new column in the array in output, corresponding to the angle of bifurcation of crack. The array as starter can comprise several crack tips . It can contain one or more times for each crack tip.

3.3.1 Operand NOM_PARA

```
◊   NOM_PARA     =       "BETA"                              [DEFAULT]
                   /   nom_angle,                            [TXT]
```

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

3.3.2 Operand CRITERE

```
◊   CRITERION    =       "SITT_MAX"                    [DEFAULT]
                 /   "K1_MAX",
                 /   "K2_NUL",
                 /   "PLANE",
```

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This operand makes it possible to choose the criterion of computation of the angle of bifurcation:

- "SITT_MAX" : criterion of the maximum circumferential stress (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.
- "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 criterion "K2_NUL" does not function for an angle higher than $60°$.

- "PLANE" : defines a null angle.

3.4 Operands for operation "K_EQ"

operation "K_EQ" creates a new column in the array in output, corresponding to the office plurality of the modes. It can contain one or more times, but the Young modulus and the Poisson's ratio in the case of office plurality of the type "CUMUL_G" or "QUADRATIQUE" must be definite constant in time.

3.4.1 Operand NOM_PARA

```
◊  NOM_PARA    =      "K_EQ"                          [DEFAULT]
                  /   nom_cumul,                       [TXT]
```

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

3.4.2 Operand CUMUL

```
◊  CUMUL    =      "CUMUL_G"                          [DEFAULT]
               /   "QUADRATIQUE",
               /   "LINEAIRE",
               /   "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 energy restitution G of the values of the Young modulus E and the Poisson's ratio ν. It is available in 2D and 3D.

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

- "QUADRATIQUE" : This office plurality is calculated starting from the values of the Poisson's ratio ν. 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:

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

- "LINEAIRE" :
  In 2D, this office plurality is written:

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

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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 operation "DELTA_K_EQ"

operation "DELTA_K_EQ" creates a new column in the array in output, corresponding to the office plurality of the modes. It can contain one or more times, but the Young modulus and the Poisson's ratio in the case of office plurality of the type "CUMUL_G" or "QUADRATIQUE" must be definite constant in time.

3.5.1 Operand NOM_PARA

```
◊  NOM_PARA    =       "DELTA_K_EQ"                    [DEFAULT]
                   /   nom_cumul,                     [TXT]
```

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

3.5.2 Operand CUMUL

```
◊  CUMUL    =       "CUMUL_G"                          [DEFAULT]
               /   "QUADRATIQUE",
               /   "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 energy restitution G of the values of the modulus Young E and of the Poisson's ratio ν. It is available in 2D and 3D.

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

• "QUADRATIQUE" : This office plurality is calculated starting from the values of the Poisson's ratio ν. 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:

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

• "MODE_I" : This office plurality is available in 2D and in 3D and is written:

$$\Delta K1$$

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3.6 Operands for operation "COMPTAGE_CYCLES"

operation "COMPTAGE_CYCLES" allows to calculate the cycles related to the evolution of one (or several) quantity (S). This operation created a new array, with a column CYCLES and a column corresponding to the variation of the quantity counted to cycle. The array as starter can comprise several crack tips.

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 COMPTAGE

♦ COMPTAGE = "RAINFLOW",
/ "RCCM",
/ "NATUREL",
/ "UNITAIRE"

This operand makes it possible to choose the method counting of the cycles. Except for counting UNITAIRE, one calls on command POST_FATIGUE. For more information on the methods of countings, to see documentation [R7.04.01]. The array as starter can contain one or more times, but corresponding to the same crack tip.

Counting UNITAIRE is a cas particulier for the linear elastic designs. In this case, the array in entry should contain one time and the variation of the quantity will then be determined by operands COEF_MULT_MINI and COEF_MULT_MAXI.

3.6.3 Operand DELTA_OSCI

◊ DELTA_OSCI=/0 . [DEFAULT]
/ DELTA, [R]

confer to the 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:
$\Delta q = q_u(cmaxi - cmini)$
where q is the quantity to be counted, and q_u the unit value of this quantity (only value contained in the array as starter).

3.7 Operands for operation "LOI_PROPA"

operation "LOI_PROPA" creates a new column in the array in output, corresponding to the unit projection (i.e. for a cycle) of a crack taking into account a model of propagation in fatigue. The array as starter can comprise several crack tips . It can contain one or more times for each crack tip.

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3.7.1 Operand NOM_PARA

```
◊   NOM_PARA        =       "DELTA_A"                [DEFAULT]
                        /   nom_da,                   [TXT]
```

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

3.7.2 Operands LOI, C, M, NOM_DELTA_K_EQ

```
♦   /    LOI=/              "PARIS"                  [DEFAULT]
    /C                =C ,                          [R]
    /M                =M ,                          [R]

◊   NOM_DELTA_K_EQ  =       " DELTA_K_EQ "           [DEFAULT]
                        /   nom_dkeq                  [TXT]
```

operand LOI makes it possible to specify the model of propagation in fatigue selected. For the moment, only the model of Paris is available. This model is written:

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

where C and m are coefficients materials, indicated by the operands C and Mr.

the column in the array of entry corresponding to ΔK_{eq} is specified by operand NOM_DELTA_K_EQ.

The unit projection then is calculated ($\Delta N=1$ implicitly):

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

Note:

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

- in mode 1 pure if $K1$ is always positive,
- in mixed mode into linear for a cycle $(0-max)$.

3.8 Operands for operation "CUMUL_CYCLES"

operation "CUMUL_CYCLES" makes it possible to cumulate a quantity on all the previously counted for each cycle by calculating the average cycles. The array created contains all the initial columns of the array, except the column CYCLES. Attention, in a point of the bottom, it is necessary that the other columns of the array do not vary during cycles. The name of the column corresponding to the quantity with office plurality does not change.

The array as starter can comprise several crack tips .

3.8.1 Operand NOM_PARA

```
◊   NOM_PARA     =       "DELTA_A"                   [DEFAULT]
                     /   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 CUMUL

```
◊   CUMUL =    ' LINEAR"                  [DEFAULT]
```

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This operand is not useful for time, 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 cyle i quantity to be cumulated.

3.9 Operands for operation "PILO_PROPA"

operation "PILO_PROPA" makes it possible to control the propagation of several crack tips (for the moment, restricted with only one crack). Control is done :
- maybe by imposing the increment amongst cycles (control in cycles);
- maybe by imposing the increment of maximum projection of the crack tip (control into advanced).

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

The array as starter must contain 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 cracks.
The other mode of control 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 operation "K1_NEGATIF"

the purpose of operation "K1_NEGATIF" is discussing the items of the bottom for which the stress intensity factor $K1$ is negative.
For these points where the values of $K1$ are negative, $K1$ is put atzero and the rate 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 array in entry, the latter must also contain the parameter $K2$ (and $K3$ in 3D).
The array of entry can comprise several times of computation and several crack tips.

3.10.1 Operand MODELIZATION

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

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

When $K1$ is null, the formula of Irwin is:

In 3D:

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

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

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

In plane stresses:

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

where E is the formula and Young modulus ν the Poisson's ratio.

3.10.2 Operand MATER

♦ MATER = mat, [material]

This operand recovers the name of the material used for computations. The material parameters 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.

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