

## Operator CALC\_G

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### 1 Goal

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This operator calculates the following sizes of breaking process, in 2D and 3D:

- the rate of refund of energy by the method theta in the case of a linear thermoelastic problem or not linear [R7.02.01] and [R7.02.03], in statics or dynamics [R7.02.02];
- stress intensity factors  $K1$ ,  $K2$  and  $K3$  by the method of singular displacements in the case of a linear thermoelastic problem [R7.02.05];
- the maximization of  $G$  and of  $KI$  under constraints terminals.

Before a first use, it is advised to refer to the reference documents and of corresponding advices of use, in particular the document [U2.05.01].

This operator generates a concept of the type `table_sdaster`.

## 2 Syntax

```
[table_sdaster] = CALC_G

(
# Recovery of the result of mechanical calculation
  ♦ RESULT = resu, / [evol_elas]
                    / [evol_noli]
                    / [dyna_trans]
                    / [mode_meca]

  # If RESULT of the evol_elas type, evol_noli or dyna_trans
  ♦ / TOUT_ORDRE = 'YES', [DEFECT]
    / NUME_ORDRE = l_ordre, [l_I]
    / LIST_ORDRE = read , [listis]
    / INST = l_inst, [l_R]
    / LIST_INST = l_reel, [listr8]

  ♦ CRITERION = / 'RELATIVE', [DEFECT]
                ♦ PRECISION = / prec, [R]
                    / 1.E-6, [DEFECT]
                / 'ABSOLUTE',
                ♦ PRECISION = prec, [R]

  # If RESULT of the mode_meca type
  ♦ / TOUT_MODE = 'YES', [DEFECT]
    / NUME_MODE = l_ordre, [l_I]
    / LIST_MODE = read , [listis]
    / FREQ = l_inst, [l_R]
    / LIST_FREQ = l_reel, [listr8]

  ♦ CRITERION = / 'RELATIVE', [DEFECT]
                ♦ PRECISION = / prec, [R]
                    / 1.E-6, [DEFECT]
                / 'ABSOLUTE',
                ♦ PRECISION = prec, [R]

# Option requested
  ♦ OPTION = | 'G',
             | 'G_EPSI',
             | 'K',

  ♦ TITLE = title, [l_Kn]

# Creation of the field theta
  ♦ THETA =_F ( ♦ / ♦ FISSURE = FF, [fond_fissRUE]
               ♦ / CHAM_THETA = chamno, [cham_no_sdaster]
               ♦ / R_INF = R, [R]
               / R_INF_FO = rz, [function]
               ♦ / R_SUP = R, [R]
               / R_SUP_FO = rz, [function]
               ♦ / DISCRETIZATION =
                 / 'LINEAR', [DEFECT]
                 ♦ NB_POINT_FOND = N, [I]
                 / 'LEGENDRE',
                 ♦ DEGREE = /5, [DEFECT]
```

```

/ 0,1,2,3,4,6,7,
),
# Loading
# If RESULT of the dyna_trans type or mode_meca
  ◇ EXCIT = _F ( ◇ LOAD = load , [char_meca]
                [char_cine_meca]
                ◇ FONC_MULT = fmult, [function]
                [formula]
                ),
# End if

# State Initial
# if the law of behavior of mechanical calculation is 'ELAS'
  ◇ ETAT_INIT = _F (SIGM = siefelga, [cham_elem, cham_no]
                    ),
# Impression of information
  ◇ INFORMATION = / 1 , [DEFECT]
                  / 2 ,
)

```

## 3 Operands

### 3.1 Operand RESULT

◆ RESULT = resu

Name of a concept result of the type `evol_elas`, `evol_noli`, `dyna_trans` or `mode_meca`. This operand makes it possible to recover the field of displacement (and speed and of acceleration for a calculation in dynamics).

The material model and field, necessary to calculation, are also extracted from the structure of data result. The possible options of calculation for each type of modeling are recalled in the table below.

	Calculation of <i>G</i>	Calculation of <i>K</i>
D_PLAN/C_PLAN, D_PLAN_INCO_UPG, D_PLAN_INCO_UP	CALC_G (OPTION 'G')	CALC_G (OPTION 'K')
AXIS, AXIS_INCO_UPG, AXIS_INCO_UP	CALC_G (OPTION 'G')	CALC_G (OPTION 'K')
3D, 3D_INCO_UPG, 3D_INCO_UP	CALC_G (OPTION 'G')	CALC_G (OPTION 'K')

Table 3.1: Availability, by modeling, of the options of calculation.

#### Remarks on the properties materials:

Characteristics of material, recovered in the structure of data `resu`, are the following ones:

- Young modulus `E`,
- Poisson's ratio `NAKED`,
- thermal dilation coefficient `ALPHA` (for a thermomechanical problem),
- elastic limit `SY` (for a nonlinear elastic problem),
- slope of the traction diagram `D_SIGM_EPSI` (for a nonlinear elastic problem with linear isotropic work hardening).

For calculation DU rate of restitution of energy, these characteristics can depend on the geometry (option 'G') and of the temperature (option 'K'). They must be independent of the temperature for the calculation of the stress intensity factors (option 'K').

Characteristics `SY` and `D_SIGM_EPSI` are treated only for one nonlinear elastic problem with work hardening of Von Mises. The calculation of the coefficients of intensity of constraints is treated only in linear elasticity.

#### Note:

*For the calculation of the stress intensity factors (option 'K'), the characteristics must be defined on all materials, including on the elements of edge, because of method of calculating [R7.02.05]. To ensure itself so it is advised to do one `AFFE = _F` (`ALL = 'YES'`) in the order `AFFE_MATERIAU [U4.43.03]`, since it is necessary to using the rule of overload then.*

*Pour incompressible elements (`_INCO_UPG`, `_INCO_UP`), it is advised to use `STAT_NON_LINE` to get the results.*

*Factors of intensity of the constraints obtained with the option 'K' are calculated by evaluating the bilinear form of *G* with a purely mechanical singular solution (asymptotic solution of Westergaard).*

If a thermomechanical problem is solved, one then does not take counts the singularity due to the thermal field of it.

An indicator of the error due to this approximation can be obtained by evaluating the difference enters  $G$  and  $G_{IRWIN}$ . In practice, one evaluates in any point of the bottom of crack the quantity  $\frac{|G - G_{irwin}|}{|G|}$ , and one makes of it then the arithmetic mean. If this average exceeds 50 %, it is estimated whereas one leaves the perimeter of validity of the approach. This checking is with the load of the user.

## Problem of bi--material:

**1<sup>er</sup> case** : There is a bi--material but the point of crack is in only one material, cf Appears 3.1-a. If one is assured that the crown, definite enters the rays inferior  $R_{INF}$  and superior  $R_{SUP}$ , has like support of the elements of same material, calculation is possible whatever the selected option. If not only L'option 'G' is possible.

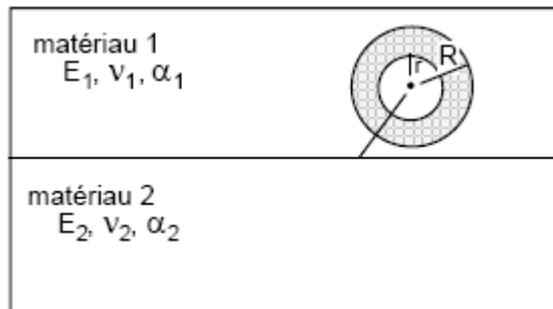


Figure 3.1-a: Bi--material: 1<sup>er</sup> case

**2<sup>nd</sup> case** : There is a bi--material where the point of crack is with the interface, cf Appears 3.1-b. To date, only L'option of calculation of the rate of refund of energy (option 'G') is available. The calculation of coefficients of intensity of constraints is not possible in this case.

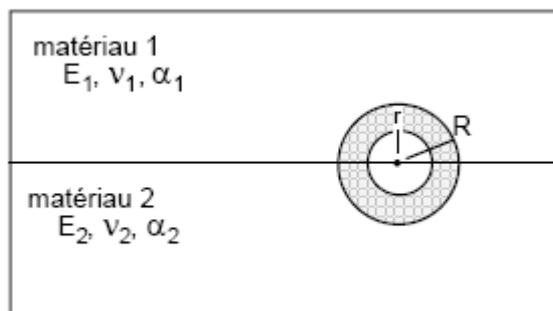


Figure 3.1-b: Bi--material: 2<sup>nd</sup> case

## 3.2 Operands

TOUT\_ORDRE/NUME\_ORDRE/LIST\_ORDRE/INST/LIST\_INST/TOUT\_MODE/NUME\_MODE/LIST\_MODE/FREQ/LIST\_FREQ/PRECISION/CRITERION

These operands are used with the operand RESULT.

Operands TOUT\_ORDRE, NUME\_ORDRE, LIST\_ORDRE, INST, LIST\_INST are associated with the results of the type evol\_elas, evol\_noli or dyna\_trans. See [U4.71.00].

Operands TOUT\_MODE, NUME\_MODE, LIST\_MODE, FREQ, LIST\_FREQ are associated with the results of the type mode\_meca.

## 3.3 Operand OPTION

- ◆ OPTION = | 'G' ,  
              | 'K' ,  
              | 'G\_EPSI' ,

### 3.3.1 OPTION = 'G' [R7.02.01] and [R7.02.03]

It allows the calculation of the rate of refund of energy  $G$  by the method theta in 2D or local 3D for a linear thermoelastic problem or not linear.

For this calculation, and the displacement stress fields of the result as starter of the operator are directly used.

### 3.3.2 OPTION = 'K' [R7.02.05]

This option calculates in 2D and 3D coefficients of intensity of constraints  $K_1$ ,  $K_2$  and  $K_3$  in linear thermoelasticity planes by the method of the singular fields (use of the bilinear form of  $G$ , [R7.02.05]), as well as the size  $G_{IRWIN}$  (see section 3.9).

**Note:**

- For this option, only the linear elastic designs without initial or elastic state linear with initial constraint are available.
- LE calculation of this option is not possible that if the lips are initially stuck ( CONFIG\_INIT=' COLLEE' in DEFI\_FOND\_FISS [ U4.82.01 ] ).

### 3.3.3 OPTION = 'G\_EPSI'

It allows the calculation of the rate of refund of energy  $G$  by the method theta in 2D or local 3D for a linear thermoelastic problem or not linear when the constraints are recomputed starting from the field of displacement and the law of behavior.

This operand is found that EN elasticity (linear or not) and without initial state resulting from the keyword ETAT\_INIT (see section 3.7).

**Note:**

- If the laws of behavior used for mechanical calculation and postprocessing are the same ones - what constitutes the normal practice - then the results with or without recalculation of the constraints are identical.  
A usual practice to take into account plasticity however consists in doing an elastoplastic mechanical calculation, followed by a nonlinear elastic postprocessing for the calculation of  $G$ . If one remains well in the field of validity of the calculation of  $G$  (radial and monotonous loading), then results with or without recalculation of the constraints,  $G$  and  $G\_EPSI$  are identical. As soon as one leaves this field of validity, the variation grows.

*This option, to hold to the informed users, thus makes it possible to check a posteriori that one remains well on the design assumptions of  $G$ .*

## 3.4 Keyword TITRE

For the operand TITRATES, one can refer to associated documentation:

```
◇ TITLE = title  
[U4.03.01].
```

## 3.5 Keyword THETA

The field theta is calculated in CALC\_G to leave keyword FISSURE.

The Councils on the choice of the crowns (in CALC\_G) :

- *To avoid using a field theta defined with a lower ray  $R_{INF}$  no one. The fields of displacements are singular in bottom of crack and introduce results vague in post - treatment of breaking process.*
- *It is advised to use the order successively CALC\_G with at least three fields theta of different crowns to make sure of the stability of the results. In the event of important variation (higher than 5-10%) it is necessary to wonder about the good taking into account of all modeling.*
- *For the option  $\kappa$  into 2D-axisymmetric, the ruffleyon of the crowns must be small in front of the ray of the bottom of crack to have the best possible precision. It is interdict to have crowns of ray larger than the ray of the bottom of crack.*

### 3.5.1 Operands CRACK

```
◆ / CRACK = FF,
```

This operand makes it possible to define to it (or them) fields theta.

FF is the bottom of crack defined by the order DEFI\_FOND\_FISS [U4.82.01] for a bottom of crack open or closed (funds double interdicts in CALC\_G).

### 3.5.2 Operand CHAM\_THETA

```
◇ CHAM_THETA = /CO ('cham_theta') [evol_noli]
```

Concept of the type `evol_noli` who contains the field theta calculated in the operator (see the reference material [R7.02.01] to know how is calculated of field). This concept contains one `cham_no` (fields with the nodes) in 2D and in 3D

### 3.5.3 Operands R\_INF, R\_INF\_FO, R\_SUP, R\_SUP\_FO

These operands make it possible to calculate the field theta when this one was not beforehand given. They correspond respectively the rays inferior and to superior of the crowns (scalar or function, in 3D, of the curvilinear X-coordinate).

The two rays can be introduced either by constant actual values which are arguments of the simple keywords `R_INF` and `R_SUP`; maybe by functions of the curvilinear X-coordinate on the bottom of crack directed, which are arguments of the simple keywords `R_INF_FO` and `R_SUP_FO`.

Some advices are given below. Lorsque the rays are not function of the curvilinear X-coordinate, the operands `R_INF` and `R_SUP` are optional. If they are not indicated, they are automatically calculated starting from the maximum  $H$  sizes of 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`. It was selected to pose `R_SUP = 4:00` and `R_INF = 2:00`. If one chooses the value automatically calculated for `R_SUP` and `R_INF`, it is advisable however to make sure that these values (displayed in the file `.mess`) are coherent with dimensions of the structure.

In the case of a defect initially opened and whose bottom is not plan, it is at present not possible to calculate the rate of refund of energy.

## 3.5.4 Operand DISCRETIZATION

The scope of application of this keyword is limited to the case 3D.

### 3.5.4.1 Operand DISCRETIZATION = LINEAR

The trace of the field theta on the bottom of crack is discretized according to the functions of form associated with the discretization with the bottom with crack ('LAGRANGE') [R7.02.01].

It is possible to reduce the number of nodes of the bottom used for a 'LINEAR' discretization with the following keyword:

```
◇ NB_POINT_FOND = nbnofo,
```

Prear defect, calculation is done on all the nodes of the bottom of crack for a crack with a grid. SI the grid is free, the number of nodes in bottom of crack can be important, which leads to very long computing times, but also with strong oscillations which do not allow a correct postprocessing on the parameters  $G(s)$  or  $K(s)$  calculated for oneE discretization 'LINEAR'.

The operand `NB_POINT_FOND` allows to fix a priori the number of points of postprocessing, in order to improve the regularity of the results. `nbnofo` points are équi-distribute along the bottom of crack.

### 3.5.4.2 Operand DISCRETIZATION = LEGENDRE

The trace of the field theta on the bottom of crack is discretized according to the base of  $N$  first polynomials of Legendre ('LEGENDRE'), [R7.02.01].

user can choose the number of polynomial which it wishes to make his calculation with the following keyword:

```
◇ DEGREE = N
```

$n$  is the maximum degree of the polynomials of Legendre used for the decomposition of the field  $\theta$  in bottom of crack.

By default  $n$  is assigned to 5. The value of  $n$  must be ranging between 0 and 7.

### 3.5.4.3 The Council on the discretization

- *it is difficult to give a preference to one or the other method of smoothing. In theory both give equivalent digital results. Nevertheless the smoothing of the type 'LINEAR' is little more expensive in time CPU than the smoothing of the type 'LEGENDRE' ;*
- *the smoothing of the type 'LEGENDRE' is sensitive to the maximum degree of the selected polynomials. The maximum degree must be defined according to the number of nodes in bottom of crack  $NO$ . If  $n$  is too large in comparison with  $NNO$  the results are poor [U2.05.01 §2.4];*

- oscillations can appear with the smoothing of the type 'LINEAR', in particular if the grid comprises quadratic elements. If the grid is radiant in bottom of crack (crack with a grid), it is then recommended to define crowns `R_INF` and `R_SUP` coinciding with the borders of the elements.
- for the cracks with a grid, when a smoothing of the type is used 'LINEAR' it is recommended to use the operand `NB_POINT_FOND` to guarantee an equal distribution of the points of calculations in bottom of crack. The choice of a report of about 5 between the total number of points in bottom of crack (to be sought in the information printed in the file message by the order `DEFI_FOND_FISS`) and the number of points of calculation seems suitable to limit the oscillations;
- the use of at least two types of smoothing with several crowns of integration and the comparison of the results are **essential** in order to check the validity of the model.

## 3.6 Keyword EXCIT and operands CHARGE/FONC\_MULT

```
◇ EXCIT = _F ( ◇ LOAD = load  
              ◇ FONC_MULT = fmult)
```

The keyword `EXCIT` allows to recover a list of loadings `load`, resulting from the orders `AFFE_CHAR_MECA` or `AFFE_CHAR_MECA_F` [U4.44.01], and possible multiplying coefficients associated `fmult`.

SI the keyword `EXCIT` is absent from order, the loading taken into account is that extracted from `resu`. If the loading is provided via `EXCIT`, then it is this loading which will be used in `CALC_G`. If the loading provided in `EXCIT` is different from that present in `resu` (coherence of the name and amongst loads, of the couples load-function), an alarm is emitted and calculation continues with the loadings indicated by the user.

However, SI the result is of type `dyna_trans` or `mode_meca`, it is possible to recover a list of loading `S` since `resu`. The taking into account of these loadings in the calculation of `G` thus requires the keyword `EXCIT`.

The loadings currently supported by various modelings and being able to have a direction in breaking process are the following ones:

- Voluminal effort: `ROTATION`, `FORCE_INTERNE`, `GRAVITY`.
- Surface effort on the lips of the crack: `FORCE_CONTOUR` (2D), `FORCE_FACE` (3D), `PRES_REP`.
- Thermal dilation: the temperature is transmitted via `AFFE_MATERIAU/AFFE_VARC`
- Initial deformation: this deformation is transm is E via the variable of order `EPSA` (unelastic deformation) in `AFFE_MATERIAU/AFFE_VARC`
- Predeformation: `PRE_EPSI` (only in case of one crack with a grid, for the option `G_EPSI`. Apart from this particular configuration, the application of one loading `PRE_EPSI` conduit with false results)

In the event of thermomechanical problem, the temperature is transmitted via the properties materials (`AFFE_MATERIAU/AFFE_VARC/EVOL`). Thermal dilation thus is automatically taken in account in calculation with `CALC_G`. It is the same if an initial deformation is transmitted via the variable of order `EPSA`.

### Note:

The loadings not supported by an option are **been unaware of**. To date, the following loadings being able to have a direction in breaking process are not treated:

- `FORCE_NODALE`
- `FORCE_ARETE`
- `DDL_IMPO`            on the lips of the crack
- `FACE_IMPO`

- `PRE_EPSI` EN outside of the only case treated "crack with a grid and option `G_EPSI`"

It is important to note that the only loadings taken into account in a calculation of breaking process with the method  $\theta$  are those supported by the elements inside the crown, where the field of vectors theta is nonnull (enters `R_INF` and `R_SUP` [R7.02.01 §3.3]). **Only types of load likely to influence the calculation of  $G$  are thus the voluminal loadings (gravity, rotation), a nonuniform field of temperature or efforts applied to the lips of the crack.**

### Caution:

- If several loadings of comparable nature (for example voluminal force) appear in calculation, they are combined between them for postprocessing. The weather is however not possible to date to be this combination so loadings of the type `FORMULA` are present : calculation finishes then in error.
- One observes also a rule of exclusion at the time of the simultaneous presence of a field of predeformations (via `'PRE_EPSI'`) and of an initial stress field.
- One observes also a rule of exclusion at the time of the simultaneous presence of a field of deformations initial (via `'EPSA'`) and of an initial stress field.
- One observes also a rule of exclusion at the time of the simultaneous presence of a field of predeformations (via `'PRE_EPSI'`) and of a field of deformations initial (via `'EPSA'`).
- It is not possible to date to associate a load defined from one `FORMULA` and a multiplying coefficient (`FONC_MULT`). In this case, calculation finishes in error.
- The loads kinematics (`AFFE_CHAR_CINE` and `AFFE_CHAR_CINE_F`), cannot be taken into account in calculation.
- For the option `K`, if a loading is imposed on the lips of the crack (`PRES_REP` or `FORCE_CONTOUR`), then it is necessary **obligatorily** to correctly direct the meshes of those (while using `ORIE_PEAU_2D` or `ORIE_PEAU_3D`) prior to calculation of `K`.
- It is noted that the calculation of `CALC_G` is available only for the results of calculations thermo - mechanical in HP (keyword `DEFORMATION = 'SMALL'`).

## 3.7 Operand ETAT\_INIT

- ◇ `ETAT_INIT=_F (SIGM = siefelga)`

In the case of a relation of elastic behavior incremental, it is possible to define a state of initial stresses not no one.

The use of this keyword requires as a preliminary the definition of an initial state in the operator `STAT_NON_LINE` at the time of the resolution of calculation post-to be treated by `CALC_G`.

`STAT_NON_LINE` this definition in two manners allows (see u4.51.03):

- with an initial state of standard result, well informed under the keyword `EVOL_NOLI` keyword factor `ETAT_INIT`
- with an initial state of fields type, well informed under the keywords `SIGM/DEPL/VARI/STRX/COHE` keyword factor `ETAT_INIT`

With this day, the post treatment with `CALC_G` calculations using the keywords `EVOL_NOLI/DEPL/VARI/STRX/COHE` is not possible. Only the post treatment with `CALC_G` calculations using the keywords `SIGM` is possible.

The initial stress field provided can be of type `SIEF_ELGA`, `SIEF_ELNO` or `SIEF_NOEU` in a modeling FEM.

In all the cases, this initial stress field must be **auto--balanced**, in absence of crack, with the only boundary conditions. The user must check that its initial stress field is licit by applying it in the keyword `ETAT_INIT` of the operator `STAT_NON_LINE`, with a linear elastic behavior (`RELATION = 'ELAS'`), with the only boundary conditions; the mechanical result must be the same stress field without additional deformations (see Figure 3.1).

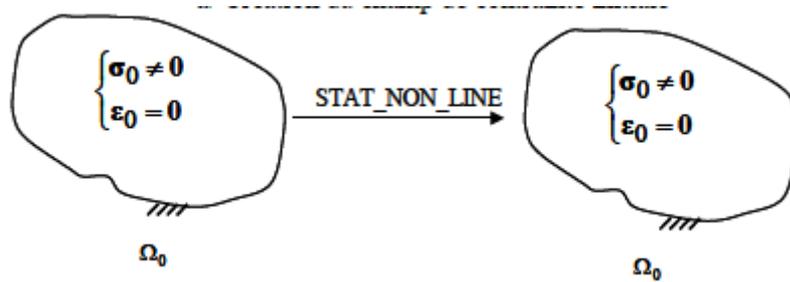


Figure 3.1 : Checking of the validity of the initial stress field.

The initial state of the structure can also be represented through a field of predeformation (via the keyword `PRE_EPSI` of the operator `AFFE_CHAR_MECA`). In this case, it is about a load included in the structure of data result (see section 3.6) and keywords `ETAT_INIT` does not have to be filled.

Taking into account the difficulty of validation of the established formulation, it is not currently licit to cumulate a predeformation (via the keyword `PRE_EPSI` of the operator `AFFE_CHAR_MECA`) and an initial constraint or an initial deformation (via the variable of order `EPSA` of `AFFE_MATERIAU/AFFE_VARC`) and an initial constraint.

### 3.8 Operand INFORMATION

◇ INFORMATION = /1, [DEFECT]  
/2,

Level of messages in the file 'MESSAGE'.

### 3.9 Produced table

The order `CALC_G` generate a concept of the type table.

This table is defined as follows for the options `G` and `K` :

In all the cases				In 2D local		In local 3D			In all the cases	
NUME_FOND	INST	NODE	NUM_PT	COORD_X	COORD_Y	COORD_Z	ABSC_CURV	ABSC_CURV_NORM	BEHAVIOR	TEMPERATURE

Table 3.9-1: Table obtained with `CALC_G` (1)

CALC_G OPTION G	CALC_G OPTION K			CALC_K_G in local 3D
G	K1	K2	G_IRWIN	K3

Table 3.9-2: Table obtained with `CALC_G` (2)

$G_{IRWIN}$ , is the rate of refund of energy obtained starting from the factors of intensity of the constraints  $K_1$  and  $K_2$  (and  $K_3$ ) with the following formulas:

$$G_{IRWIN} = \frac{1}{E} (K_I^2 + K_{II}^2) \text{ in plane constraints}$$

$$G_{IRWIN} = \frac{(1-\nu^2)}{E} (K_I^2 + K_{II}^2) \text{ in deformations plane and axisymmetric}$$

$$G_{IRWIN} = \frac{(1-\nu^2)}{E} (K_I^2 + K_{II}^2) + \frac{K_{III}^2}{2\mu} \text{ in 3D}$$

with  $E$  Young modulus and  $\nu$  Poisson's ratio and  $\mu = \frac{E}{2(1+\nu)}$ . The comparison enters  $G$  and

$G_{IRWIN}$  allows to make sure of the coherence of the results: a too important variation must result in checking the parameters of calculation (refinement of the grid, choice of the crowns for theta, smoothing in 3D...).

The order `IMPR_TABLE [U4.91.03]` allows to print the results with the desired format.

## 4 Standardisation of the rate of refund G

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### 4.1 2D plane constraints and plane deformations

In dimension 2 (plane constraints and plane deformations), the bottom of crack is tiny room to a point and the value  $G(\theta)$  exit of the order CALC\_G is independent of the choice of the field  $\theta$  :

$$G = G(\theta) \quad \forall \theta \in \Theta$$

### 4.2 Symmetry of the model

If one models only half of the solid compared to the crack:

- that is to say to specify the keyword SYME = 'YES' in the orders concerned;
- that is to say not to forget to multiply by 2, values of the rate of refund of energy  $G$  or  $G(s)$  and by 4 those of  $G_{Irwin}$ . Moreover values of the factors of intensity of the constraints corresponding to the mode of symmetry must also be multiplied by 2.

## 5 Examples

### 5.1 Example of use in 3D

Let us take the case of a crack with a grid:

The bottom of crack is defined in `DEFI_FOND_FISS` :

```
ff=DEFI_FOND_FISS ( MAILLAGE=MA,  
                    FOND_FISS=_F (GROUP_MA = 'LFF'),  
                    )
```

Examples of calculation of the rate of refund of energy in 3D (local):

```
G1LOC = CALC_G ( OPTION      = 'G',  
                 RESULT     = resu,  
                 THETA      = _F ( CRACK      = FF,  
                                   R_INF      = 1. ,  
                                   R_SUP      = 2. ,  
                                   DISCRETIZATION = 'LINEAR' ),  
                 )
```

Example of calculation of the factors of intensity of the constraints in 3D:

```
KLOC  = CALC_G ( OPTION      = 'K',  
                 RESULT     = resu,  
                 THETA      = _F ( CRACK      = FF,  
                                   R_INF      = 1. ,  
                                   R_SUP      = 2. ,  
                                   DISCRETIZATION = 'LINEAR' ),  
                 )
```

One can find examples of use in the following tests:

- SSLV110 [V3.04.110] Semi-elliptic crack in infinite medium
- SSLV112 [V3.04.112] Circular crack in infinite medium
- HPLV103 [V7.03.103] Thermoelasticity with circular crack in infinite medium.