Procedure MACR_ECREVISSE

Summary:

The macro-order MACR_ECREVISSE is to calculate the flow of fluid (air/vapor/liquid) through one (or several) fissures (S) crossing (S) in a structure modelled in 2 dimensions. It realizes for that, with each step of time, the chaining of two codes:

- *Code_Aster* who allows to know the thermomechanical state of the structure
- Crayfish which carries out the thermohydraulic calculation of flow through the crack.

In practice, the macro-order is given the responsibility to carry out successively for all the steps of time:

- a linear thermal calculation
- a quasi-static mechanical calculation
- to call the macro-order CALC_ECREVISSE, which it will be in load:
  1. to recover the profile of the crack
  2. to call a third macro-order MACR_ECRE_CALC who will generate the command file and will launch Crayfish
  3. to extract and copy the results
  4. to check the imposed criteria are checked and if need be redécouper the step of time.

The principal concept of exit is the structure of data result of mechanical calculation (evol_noli). It is also possible to obtain the structure of data results of thermal calculation, like 2 tables, one containing the flows at every moment, the other recapitulating the data relating to the cracks. By creating a repertoire of exit in the profile of study, one will be able to recover all the exits there relating to Crayfish.
It is possible to carry out continuations of calculation.

Notice

> *It is necessary to specify the keyword DEBUG=_F (HIST_ETAPE=' OUI') in BEGINNING or CONTINUATION to use MACR_ECREVISSE.*

Contents

1 Goal

This order allows the chaining of Code_Aster with the software CRAYFISH. The principle rests for each step of time, with a successive call to:

- `THER_LINEAIRE` to obtain the thermal state of the structure
- `STAT_NON_LINE` to obtain the mechanical state of the structure
- with the code CRAYFISH to know the conditions of flow of the fluid.

Notice

> *It is necessary to specify the keyword `DEBUG=_F (HIST_ETAPE=' OUI')` in `BEGINNING` or `CONTINUATION` to use `MACR_ECREVISSE`.*

2 Syntax

```
MACR_ECREVISSE    (

      # OUTGOING CONCEPTS
            ◊ TABLE     = CO ('table')                                  [CO]
            ◊ FLOW      = CO ('flow')                                   [CO]
            ◊ TEMPER    = CO ('temp')                                   [CO]

      # ETAT_INITIAL
            ◊ ETAT_INIT = _F (
                  ♦ EVOL_NOLI       = evol_noli
[evol_noli]
                  ♦ EVOL_THER       = evol_ther
[evol_ther]
                  ♦ NUME_ORDRE      = nume_ordre                        [I]
                        ),

      # MODEL THERMOMECHANICAL
                  ♦ MODELE_MECA     = m_meca                [modele_sdaster]
            ♦ MODELE_THER     = m_ther                [modele_sdaster]

      # LISTS MOMENTS
            ♦ LIST_INST = list_inst                         [listr8]

      # GIVEN FOR STAT_NON_LINE AND THER_LINEAIRE
            ♦ CHAM_MATER = chmat                            [cham_mater]
            ♦ TEMP_INIT  = tempinit                         [R]
            ◊ CARA_ELEM  = carac                            [cara_elem]
            ♦ EXCIT_MECA    = _F (
                  ♦ LOAD            = chi
[char_meca]
                  ◊ FONC_MULT       = fi                          [function]
                  ◊ TYPE_CHARGE     =     / 'FIXE_CSTE'           [DEFECT]
                                          / 'SUIV'
                                          / 'DIDI'
                                    )
            ♦ CONTACT    = char_contact                     [char_contact]
            ♦ EXCIT_THER      = _F (
                  ♦ LOAD      = chi
[char_ther]
                  ◊ FONC_MULT = fi                                [function]
```

```
                               )

            ♦ BEHAVIOR  = _F  (see the document [U4.51.11])
            ◊ NEWTON          = _F  (see the document [U4.51.03])
            ◊ CONVERGENCE     = _F  (see the document [U4.51.03])
            ◊ ENERGY          = _F  (see the document [U4.71.02])

      # GIVEN GEOMETRICAL RELATING TO THE CRACK
            ♦ CRACK           = _F (
                  ♦ GROUP_MA        =     gma                   [grma]
                  ♦ GROUP_NO_ORIG   =     ogno                  [grno]
                  ♦ GROUP_NO_EXTR   =     egno                  [grno]
                  ♦ SECTION         =     / "ELLIPSE"
                                          / "RIGHT-ANGLED"
                  ◊ LISTE_COTES_BL  =     / (0, max (abs_curv))  [DEFECT]
                                          / lcbl                [listr8]
                  ♦ LISTE_VAL_BL    =      lvbl                 [listr8]
                  ♦ ZETA            = zeta                            [R]
                  ♦ ROUGHNESS             = eps
      [R]
                  ♦ OUVERT_REMANENTE= ouv_rem                         [R]
                  ◊ TORTUOSITY      =/1                   [DEFECT]
                                      / wrong                         [R]
                  ◊ PREFIXE_FICHIER =     /'FISSURE1'           [DEFECT]
                                          /'prefix'                  [KN]
                               ),

      # RELATIVE DATA WITH THE FLOW
            ♦ FLOW      = _F (
                  ♦     / PRES_ENTREE     =     EP              [R]
                        / PRES_ENTREE_FO  =     fpe       /     [function]
                                                          /
      [tablecloth]
                                                          /     [formula]
                  ♦     / PRES_SORTIE     =     PS              [R]
                        / PRES_SORTIE_FO  =     fps       /     [function]
                                                          /
      [tablecloth]
                                                          /     [formula]
                  ♦ FLUIDE_ENTREE          =    /1,
                                                /2,
                                                /3,
                                                /4,
                                                /5,
                                                /6
                  # if FLUIDE_ENTREE = 1,3,4 or 6
                  ♦/TEMP_ENTREE            =    you                   [R]
                    / TEMP_ENTREE_FO       =    fte       /     [function]
                                                          /
      [tablecloth]
                                                          /     [formula]
                  # if FLUIDE_ENTREE = 2 or 5
                  ♦/TITR_MASS       =     Xe                    [R]
                    / TITR_MASS_FO         =    fxe       /     [function]
                                                          /
      [tablecloth]
                                                          /     [formula]
                  # if FLUIDE_ENTREE = 4 or 5
                  ♦/PRES_PART       =     pae                   [R]
```

```
                    / PRES_PART_FO        =     fpae         /     [function]
                                                             /
[tablecloth]
                                                             /     [formula]
                              ),


# CHOICE OF THE MODELS FOR CRAYFISH
          ♦ MODELE_ECRE     = _F (
               ◊ IVENAC                =     / 0,               [DEFECT]
                                             / 1,
               ♦ FLOW            =     / 'SATURATION',
                                                        / 'COLD',
               # if FLOW   = 'COLD'
               ♦ PRESS_EBULLITION      = peb,                        [R]

               ♦ FRICTION        =     / -14,
                                             / -12,
                                             / -11,
                                             / -4,
                                             / -3,
                                             / -2,
                                             / -1,
                                             / 0,
                                             / 1,
                                             / 2,
                                             / 3,
                                             / 4,
                                             / 11,
                                             / 12,
                                             / 14,
                                             / 21,
                                             / 22,
                                             / 23,
                                             / 24,
               # if negative FRICTION
               ♦ REYNOLDS_LIM          =     relim                   [R]
               ♦ FROTTEMENT_LIM        =     frtlim                  [R]
               ♦ TRANSFERT_CHAL        =     / -12,
                                             / -11,
                                             / -2,
                                             / -1,
                                             / 0,
                                             / 1,
                                             / 2,
                                             / 11,
                                             / 12,
               # if negative TRANSFERT_CHAL
               ♦ XMINCH                =      xminch                 [R]
               ♦ XMAXCH                =      xmaxch                 [R]

# CONVERGENCE CRITERIA OF THE MACRO-COMMANDE
          ♦ CONV_CRITERE    = _F (
               ♦ TEMP_REF              =      tref                   [R]
               ♦ PRES_REF              =      pref                   [R]
               ♦ CRITERION             =     / 'TEMP_PRESS'     [DEFECT]
                                             / 'TEMP'
                                             / 'CLOSE'
                                             / 'CLARIFIES'
```

```
                    # if CRITERION different from EXPLICIT
                    ◊ NUME_ORDRE_MIN         =     N                       [I]
                    ◊ PREC_CRIT              =     prec                    [R]
                    ◊ SUBD_NIVEAU            =     Nb                      [I]
                    ◊ SUBD_PAS_MINI          =     nbpas                   [R]
                                       ),
      # CONVERGENCE DIGITAL OF CRAYFISH
                ◊ CONVERGENCE_ECREVISSE      = _F (
                    ◊ KGTEST                 =     / kgtest                [R]
                                                   / 0.5             [DEFECT]
                    ◊ ITER_GLOB_MAX          =     / itnmax                [I]
                                                   / 400             [DEFECT]
                    ◊ CRIT_CONV_DEBI         =     / precdb                [I]
                                                   / 1.E-5           [DEFECT]
                                                   ),
      # GENERAL
                ◊ CURVED    =     / 'NO'                             [DEFECT]
                                  / 'POSTSCRIPT'                          [KN]
                                  / 'INTERACTIVE'                         [KN]
                ♦/SOFTWARE  =     software                           [KN]
                  / VERSION       =     '3.2.2'                           [KN]

                ◊ HEADING         =     title
                ◊ IMPRESSION      =     / 'NOT'                      [DEFECT]
                                        / 'YES'
            ◊       INFORMATION              =     / 1
      [DEFECT]
                                        / 2
                )
```

3 Operands

3.1 Operands TABLE/TEMPER/FLOW

```
◊ TEMPER   = CO ('temp')
◊ TABLE    = CO ('table')
◊ FLOW = CO ('flow')
```

These keywords make it possible to give the name of the concepts leaving the macro-order, namely

- `TABLE` : a table of 7 columns giving for each step of time: the dimension z , flow, total pressure (Pa), the temperature of the fluid ($°C$), the coefficient of exchange by convection ($W.m^{-2.}°C^{-1}$), the name of the crack.
- `TEMPER` : the structure of data result of thermal calculation
- `FLOW` : the value of the flow ($kg.s^{-1}$) with each step of time and for each crack

Note:

1. *all the concepts of exit are optional; it nevertheless is highly advised to inform has minimum `TEMPER`, if not it is impossible to control the fields of temperature in the structure and to make a continuation*
2. *if the concept is réentrant, the keyword* `TEMPER` *does not have to be here well informed but under the keyword `ETAT_INIT`, operand `EVOL_THER`.*

3.2 Keyword ETAT_INIT

```
◊ ETAT_INIT    = _F (
        ♦ EVOL_NOLI    = evol_noli
        ♦ EVOL_THER    = evol_ther
        ♦ NUME_ORDRE   = nume_ordre
```

Keyword allowing to define the initial state within the framework of a continuation of the macro-order.

3.2.1 Operand EVOL_NOLI

Name of the concept of the type `evol_noli` from where will be extracted the mechanical state.

3.2.2 Operand EVOL_THER

Name of the concept of the type `evol_ther` from where will be extracted the thermal state. This concept will be enriched during calculation.

3.2.3 Operand NUME_ORDRE

The initial state to continue calculation will be defined starting from the number of filing `NUME_ORDRE` for `evol_noli` and for `evol_ther`.

3.3 Operands MODELE_MECA/MODELE_THER

```
♦ MODELE_MECA     = m_meca
♦ MODELE_THER     = m_ther
```

These keywords make it possible to inform the name of the model (`m_meca`) whose elements are the object of mechanical calculation and the name of the model (`m_ther`) whose elements are the object of thermal calculation.

3.4 Operand LIST_INST

```
♦ LIST_INST =      list_inst
```

List of the steps of times which correspond to the imposed moments of calculation. In the event of recutting, the moments are inserted in this list.

3.5 Operand CHAM_MATER

```
♦ CHAM_MATER     =     chmat
```

Name of the affected material field to the grid. Attention, this field must understand the data associated with the mechanical behavior and the thermal behavior (keyword THER of DEFI_MATERIAU).

3.6 Operand TEMP_INIT

```
♦ TEMP_INIT      =     temp_init
```

Value of the initial temperature on all the field.

3.7 Operand CARA_ELEM

```
◊ CARA_ELEM       = carac
```

This keyword makes it possible to inform, the characteristics of the elements of beam, bars, hull, pipe, discrete element, when they are present in the model. Attention, this keyword is used only for mechanical calculation but is not transmitted for the operator of thermics (to avoid any problem with the bars).

3.8 Keyword EXCIT_MECA

```
♦ EXCIT_MECA   = _F (
        ♦ LOAD          = chi
        ◊ FONC_MULT        = fi
        ◊ TYPE_CHARGE =   / "FIXE_CSTE"
                          / "SUIV"
                          / "DIDI"
                         )
```

It is a question here of informing the boundary conditions of the mechanical problem, as well as the possible mechanical loadings which apply to the structure. Syntax is identical to that of the keyword EXCIT of STAT_NON_LINE but it is not possible to control a loading. See the document [U4.51.03].

3.9 Keyword CONTACT

```
♦ CONTACT =      char_contact
```

One informs here the conditions of contact between the lips of the crack, which can be closed during calculation. The goal of this keyword is that to avoid the interpenetration of the lips which can occur under the effect of the flow of the fluid.

3.10 Keyword EXCIT_THER

```
♦ EXCIT_THER   = _F (
           ♦ LOAD      = chi
           ◊ FONC_MULT     = fi
                    )
```

It is a question here of informing the boundary conditions of the thermal problem as well as the possible thermal loadings. Syntax is identical to that of the keyword EXCIT of THER_LINEAIRE.
See the document [U4.54.01].

3.11 Keyword BEHAVIOR

It is a question here of informing the law of behavior which will be used to solve the mechanical problem. See the document [U4.51.03].

3.12 Keyword NEWTON

It is a question here of informing the parameters of the algorithm of Newton to solve the mechanical problem. This keyword is identical to that of STAT_NON_LINE, it is thus advisable to refer to the document [U4.51.03].

3.13 Keyword CONVERGENCE

It is a question here of informing the convergence criteria for mechanical calculation. Syntax corresponds to that of STAT_NON_LINE (see the document [U4.51.03]).

Note:

It can be necessary to use RESI_GLOB_MAXI rather than RESI_GLOB_RELA, when there is no mechanical loading (if not, null effort, therefore RESI_GLOB_RELA indefinite).

3.1 Keyword ENERGY

This keyword makes it possible to activate the calculation of the assessment of energy and its posting during mechanical calculation (see the document [R4.09.01]). This assessment is stored in the table of name PARA_CALC from where it can be extracted using the order RECU_TABLE [U4.71.02].

3.2 Keyword CRACK

♦ CRACK

This keyword makes it possible to define all the parameters having milked in a crack. Several occurrences of this keyword are possible if there are several cracks.

3.2.1 Operand GROUP_MA

♦ GROUP_MA = gma

Groups of the meshs defining the lips of the crack. One gives the group of the lower lip and higher.

3.2.2 Operands GROUP_NO_ORIG and GROUP_NO_EXTR

♦ GROUP_NO_ORIG = ogno

♦ GROUP_NO_EXTR = egno

Allows to define the two groups of nodes which define the two ends of the cracks in order to direct it.

3.2.3 Operand SECTION

```
♦ SECTION  =/"ELLIPSE"
                                  /"RIGHT-ANGLED"
```

It is a question here of defining the bypass section of the flow (plan perpendicular to the plan of modeling). This one can be elliptic or rectangular. One of dimensions of this section corresponds in keeping with the crack in the plan of modeling. This one is at every moment given by the macro-order. Other dimension corresponds in keeping with the crack out of plan of modeling. This one is fixed during all calculation and must be indicated thanks to the operands LISTE_COTES_BL and LIST_VAL_BL.

3.2.4 Operand ROUGHNESS

♦ ROUGHNESS = eps

Absolute roughness of the wall (in meters). This value influences the result only if friction is calculated by Crayfish (operand FRICTION >0) and if the flow is not laminar any more.
For the options of friction $21, 22, 23, 24$ it is the diameter of coarsest aggregate (flow in a crack in concrete).

3.2.5 Operands LISTE_COTES_BL/LISTE_VAL_BL

◊ LISTE_COTES_BL = lcbl
♦ LISTE_VAL_BL = lvbl

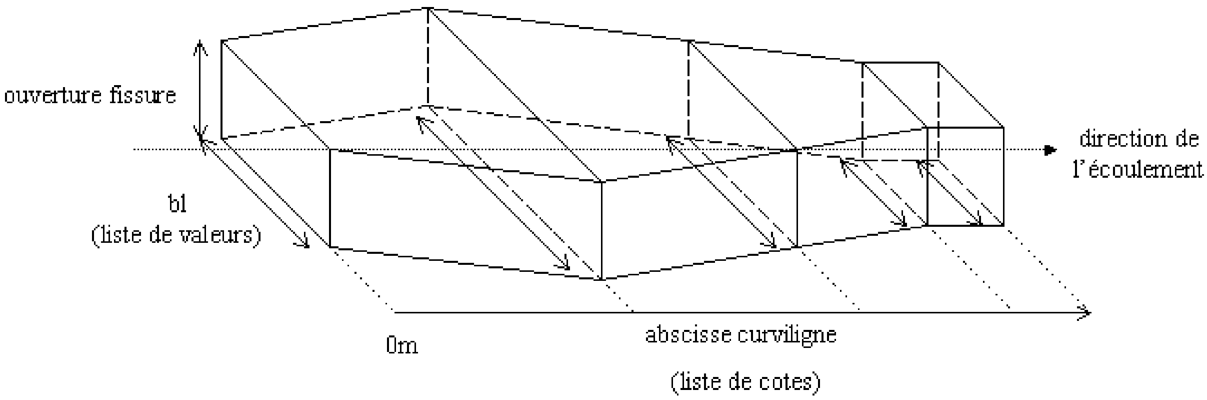

Figure 3.2.5-1: Representation of the crack

To characterize the size of the crack in the plan not modelled, it is necessary to provide the value of the "small "axis of the elliptic section or the width of the rectangular section at least in 2 points. LISTE_COTES_BL allows to inform the curvilinear X-coordinates where the dimension of the crack is given and LIST_VAL_BL allows to give dimension. If LISTE_COTES_BL is not informed, LISTE_VAL_BL must contain the width of the crack at the entry and the exit of the crack.

3.2.6 Operand ZETA

♦ ZETA = zeta
Loss ratio of singular load at the entry (without dimension).

3.2.7 Operand OUVERT_REMANENTE

♦ OUVERT_REMANENTE = ouv_rem

Value of the remanent opening (in meters) for calculation Crayfish corresponding to the real hydraulic opening of the crack when the two lips are with the contact. This translated the fact that, even when the crack is closed, a small amount of fluid will forward, in particular because of roughness. This parameter depends on material: for example, it is about $10\mu m$ for the concrete.
This keyword is thus taken into account thus during hydraulic calculation (Crayfish), but not by *Code_Aster* : IL can thus arrive well that hydraulic calculation is carried out with the remanent opening, is that the contact is activated in mechanical calculation.

3.2.8 Operand TORTUOSITY

◊ TORTUOSITY = wrong

If the crack is tortuous, one can admit that, seen fluid, the length of the crack is higher than the thickness of the crossed wall. This coefficient, which by default is worth 1, makes it possible to take into account this phenomenon. The length of the crack will be thus equal to $\frac{L}{tort}$ with $tort \leq 1$

3.2.9 Operand PREFIXE_FICHIER

◊ `PREFIXE_FICHIER = prefix`

Allows to define the name of the output files Crayfish in the file `REPE_OUT` (curves and textual files), and thus to distinguish the files associated with each crack.

3.3 Keyword FLOW

♦ `FLOW`

It is a question in this keyword of defining the nature of the fluid and its characteristics.

3.3.1 Operands PRES_ENTREE/PRES_ENTREE_FO

```
♦     / PRES_ENTREE          =     EP
            / PRES_ENTREE_FO  =     fpe
```

This operand makes it possible to give the total pressure (Pa) or its evolution in the course of time, upstream of the crack. It must be understood enters $215.10^5 Pa$ and $10^5 Pa$.

3.3.2 Operands PRES_SORTIE/PRES_SORTIE_FO

```
♦     / PRES_SORTIE     =     EP
            / PRES_SORTIE_FO  =     fpe
```

This operand makes it possible to give the total pressure (Pa) or its evolution in the course of time, at exit of the crack. It must be understood enters $215.10^5 Pa$ and $800 Pa$ and being lower with the pressure of entry (if not, there is no flow and calculation stops).

3.3.3 Operand FLUIDE_ENTREE

♦ `FLUIDE_ENTREE   =    1,2,3,4,5 or 6`

This operand makes it possible to define the state of the fluid at the entrance of the crack:

1: Supercooled or saturated water;
2: Diphasic fluid;
3: Saturated or overheated vapour;
4: Air + overheated vapor;
5: Air + saturated vapour;
6: Air alone.

According to the situation of the fluid, only some of the following characteristics are to be informed.

3.3.4 Operands TEMP_ENTREE/TEMP_ENTREE_FO

```
♦     / TEMP_ENTREE          =     you
            / TEMP_ENTREE_FO  =     fte
```

This operand makes it possible to inform the temperature ($°C$) or its evolution in the course of time, upstream of the crack. It must be indicated if the fluid at the entry is “supercooled or saturated Water”, “saturated or overheated Vapour”, “Air + overheated vapor” or “Air alone”.
(operand `FLUIDE_ENTREE = 1,3,4, or 6)`.

3.3.5 Operands TITR_MASS/TITR_MASS_FO

```
♦     / TITR_MASS        =    Xe
            / TITR_MASS_FO     =    fxe
```

This operand makes it possible to inform the mass vapor title, or its evolution in the course of time, upstream of the crack. It corresponds to the relationship between the vapor mass and the mass of water liquid and vapor. It must be indicated if the fluid at the entry is “Fluid diphasic” or “Air + saturated vapour” (operand `FLUIDE_ENTREE = 2 or 5`).

3.3.6 Operands PRES_PART/PRES_PART_FO

```
♦    / PRES_PART        =      pae
           / PRES_PART_FO     =      fpae
```

This operand makes it possible to inform the pressure partial of air (Pa) or its evolution in the course of time, upstream of the crack. It must be indicated if the fluid at the entry is “Air + overheated vapor” or “Air + saturated vapour” (operand FLUIDE_ENTREE=4 or 5).

3.4 Keyword MODELE_ECRE

♦ MODELE_ECRE
This keyword makes it possible to inform the models which will be used by Crayfish to calculate the flow of the fluid.

3.4.1 Operand IVENAC

◊ IVENAC = 0 or 1,
When this operand is activated (IVENAC=1), calculation CRAYFISH is carried out with taking into account of the vena contracted (pressure loss as starter). If not (case by default), calculation will be carried out without this option of modeling.

3.4.2 Operand FLOW

```
♦ FLOW      =     / 'SATURATION',
                                     / 'COLD'
```

In the absence of air and in the presence of water (operand FLUIDE_ENTREE=1 or 2), this operand makes it possible to choose between the homogeneous model with balance and the model of flow “ COLD ” characterized by a nonworthless fraction of metastable liquid.

3.4.3 Operand PRESS_EBULLITION

Pressure of boiling (Pa) to provide only for the model of cold flow.

3.4.4 Operand FRICTION

It is a question here of defining how friction is calculated. The valid values are: $-14,-12,-11,-4,-3,-2,-1,0,1,2,3,4,11,12,14,21,22,23,24$.

The value 0 corresponds to a calculation without friction.

For the negative values, the user fixes the value of the coefficient of friction for the turbulent flows.

For the positive values, friction in turbulent flow is calculated starting from the coefficient of roughness. In particular, options $21,22,23,24$ correspond to the relation of friction of Greiner and RAM [Bib.6] for the flow in a crack in the concrete; roughness is in this case the diameter of the coarsest aggregate. Moreover, for the values higher than 10 , the law used for the laminar flow (friction proportional contrary to Reynolds number) is connected with that in turbulent flow (constant value of the coefficient of friction). Otherwise, a discontinuity is present.

The second figure (1,2,3,4) of each option (units) determines the option of calculation of dynamic viscosity for the diphasic flows, cf documentation Crayfish [Bib.1] [Bib.2] [Bib.3] [Bib.4] [Bib.5] .

3.4.5 Operands REYNOLDS_LIM/FROTTEMENT_LIM

Coefficient of Reynolds limiting and coefficient of friction imposed for a Reynolds higher than the limiting Reynolds.
To provide only if FRICTION < 0.

3.4.6 Operand TRANSFERT_CHAL

This operand makes it possible to determine whether one wants or not to take into account the transfer of heat by convection between the fluid and the wall. The valid values are: $-12,-11,-2,-1,0,1,2,11,12$.
Value 0 corresponds to a calculation without transfer of heat (adiabatic).
The other values correspond to various options for the calculation of the convection coefficient (differences only for the laminar mode). To refer to documentation Crayfish.

3.4.7 Operands XMINCH/XMAXCH

This operator has direction only in the diphasic cases, if TRANSFERT_CHAL < 0. It makes it possible to inform the value of the mass gas titles delimiting the zone of transition between the models from calculation from the convection coefficient, cf documentation Crayfish.

3.5 Keyword CONV_CRITERE

The macro-order calculates three criteria at every moment making it possible to estimate the importance of the changes occurred between two steps of time and thus the validity of the chaining carried out. To calculate these criteria, the user must define values of reference for the pressure and the temperature, allowing to quantify the acceptable variation.

$$e_T=\frac{Max(T_t-T_{\text{t-1}})}{T_{\text{REF}}}$$
$$e_P=\frac{Max(P_t-P_{\text{t-1}})}{P_{\text{ref}}}$$
$$e_G=\sqrt{e_T^2+e_P^2}$$

Then, it can activate if it wishes it the recutting of the step of time if the value of the criterion is lower than a given value.
The gained experience watch however that it is to better try to optimize the list of moment to count on the recutting of the step of time, because calculations Crayfish are relatively long.

.

3.5.1 Operand CRITERION

Allows to define the nature of the criterion used to manage the steps of time in the macro-order. The possible values are:

- EXPLICIT : no recutting some is the value of the indicators
- TEMP : there will be recutting according to the value of e_T
- NEAR : there will be recutting according to the value of e_P
- TEMP_PRES : there will be recutting according to the value of e_G

3.5.2 Operand TEMP_REF

Temperature of reference for the calculation of the criterion in temperature of the macro-order.

3.5.3 Operand PRES_REF

Pressure of reference for the calculation of the criterion in pressure of the macro-order.

3.5.4 Operand PREC_CRIT

Value with which one compares the error obtained to activate or not the recutting of the step of time (1 by default). For example for the temperature: $e_T<\text{PREC\_CRIT}$

3.5.5 Operand NUME_ORDRE_MIN

Sequence number from which the criterion of error is taken into account. Convergence is forced on the lower sequence numbers. One often uses this operand to start the activation of the criterion of error starting from the second step of time and to force convergence on the first step which is often delicate to treat, since one imposes brutal loadings on the initial moment.

3.5.6 Operand SUBD_NIVEAU

Number of recutting of the step of authorized time. Beyond this value, one redécoupe more and one leave the macro-order.

3.5.7 Operand SUBD_PAS_MINI

Pas de time in lower part of which one does not cut out any more.

3.6 Keyword CONVERGENCE_ECREVISSE

3.6.1 Operand KGTEST

Parameter of the iterative Crayfish algorithm.
Must be understood enters 0 and $1.$. Fixed by default at $0{,}5$, one can have to so put a slightly lower value difficulties of convergence on the flow are observed.

3.6.2 Operand ITER_GLOB_MAXI

Maximum number of iterations authorized for the calculation of the flow (400 by defaults).

3.6.3 Operand CRIT_CONV_DEBI

Precision used for the convergence of the calculation of the flow. It is the value compared to which Crayfish tests the flow max and min in its process of calculation.

$$\frac{G_{max}-G_{min}}{G}\leqslant \mathrm{CRIT\_CONV\_DEBI}$$

By default with 10^{-5} , values until 10^{-2} improve the computing time without losing much precision.

3.7 Operand CURVES

```
◊ CURVED    =    / "NO"                          [DEFECT]
                 / "POSTSCRIPT"
                 / "INTERACTIVE"
```

Allows to generate or not the curves of Crayfish exit. If the curves are generated, they are stored in the file REPE_OUT with the format postscript (every moment is in the same file postscript). In interactive mode, the curves are displayed for each step of time.

3.8 Operand SOFTWARE

Allows to specify "into hard" the way to find achievable Crayfish. Now, only versions 3.2,3.2.1 and 3.2.2 are compatible with the MACR_ECREVISSE. It is necessary obligatorily to inform this operand or alternatively the operand VERSION.

3.9 Operand VERSION

Indicate the Crayfish version used in the coupling. It is necessary obligatorily to inform this operand or alternatively the operand SOFTWARE. Now, version 3.2.2 is used. It is the only one that one can inform under the operand VERSION. If one wishes to use another version (3.2 or 3.2.1), this one must be indicated under the operand SOFTWARE.

3.10 Operand HEADING

Is used to give a title to calculation Crayfish.

3.11 Operand IMPRESSION

When the operand is worth 'YES', the macro one prints a summary table of the results of Crayfish along the curvilinear X-coordinate (temperature, pressure, flow, speed, convection coefficient,…).

3.12 Operand INFORMATION

INFO=1 : almost no posting.
INFO=2 : poster information concerning the convergence criteria.

4 Operation of the coupling

4.1 Principle

This macro-order was developed within a precise framework: to estimate the flows of a crack in a concrete block modelled in 2D, possibly containing the steels modelled in the form of bar (not taken into account in thermal calculation). The use in very other framework must thus be done with the greatest precaution. However, it in fact 3 macro-order imbricated there, which can make it possible to use only part of the features.

The algorithm is the following:

```
Beginning of macro
    Buckle on the list of moments
    MACR_ECREVISSE.py
    Recovery loading thermal and mechanical
    Execution of THER_LINEAIRE
    Projection of the thermal loading and definition of the loadings coming from Crayfish
    Exécutionde STAT_NON_LINE
    Entry in CALC_ECREVISSE.py
        Recovery of the opening of the crack (POST_RELEVE_T)
        Recovery of the temperature in edge of crack
        Entry in MACR_ECRE_CALC.py
            CRAYFISH execution
            Recovery of the calculated flow and the tables of results
    Extraction and copy of the outgoing data (CL, thermics, Crayfish result…)
    Evaluation of the convergence criteria (error in temperature and/or pressure)
    Possible Recutting of the step of time even stop following the conditions
Recovery of information and concepts (loading,…)
```

The detail of the intermediate macro-orders, CALC_ECREVISSE and MACR_ECRE_CALC, is given in appendix.

4.2 Units

One can usually do without the units in *Code_Aster* while remaining coherent. However, for the needs for Crayfish, it is important to respect the international system of units here (IF), in particular for the lengths (m), pressures (Pa), and temperatures ($°C$).

4.3 Some advices of use

grid must be in 2 dimensions, and the crack with a grid explicitly. So that calculation is of good quality, it is necessary to optimize the grid so that it is compatible with the phenomena which one wants to represent: mechanical loadings, thermal loadings but also the flow of the fluid. It is thus important sufficiently to refine the grid at the edges of the crack if one wants to see to warm up material. As starter of cracks, the thermal and hydraulic phenomena are fast, it is thus necessary there too to refine the grid sufficiently.

discretization in time is also very important and must be sufficiently fine, under penalty of having important variations in the answers. Better is worth to try to optimize this list of moments rather than to rest only on the criteria for redécouper because this strategy is much more expensive in time.

For calculations with condensation vapor on the way of cracking, the convection coefficient can increase up to two orders of magnitude on the way in the liquid state. As condensation takes place on a very small zone in space, the variation of the convection coefficient and thus of the heat flow transferred to the wall can be very fast (see Figure 4.3-1).
That can generate space oscillations in the temperature of the solid mass.

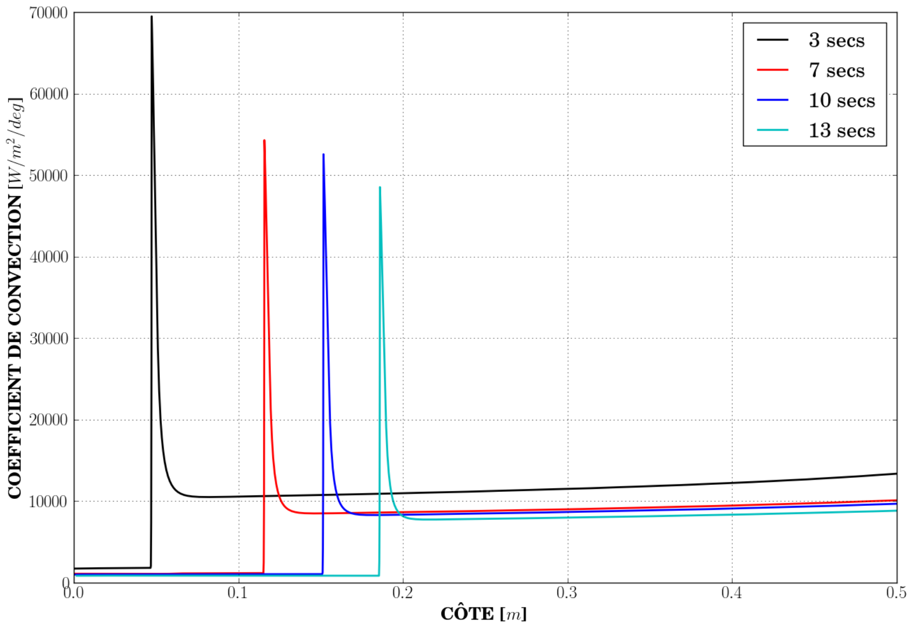

Figure 4.3-1: Convection coefficients at several moments of a calculation with condensation of the vapor.

The macro-order can be réentrante. The thermal and mechanical results will be well enriched, on the other hand of new tables of exit will be created for the new list of step of time.

Note:

> *The loadings are destroyed with each step of time, as well as the material field, possible postprocessings are in fact limited (internal displacement, constraint and variables at the points of Gauss).*

5 Example of use

See testS zzzz218a, B and C.
See also the tests zzzz354 (a-h) and zzzz355 (a-h).

6 Reference Crayfish

[Bib.1] C. Hervouet (2004). " Simulation of air/water flow/vapor through a crack: software CRAYFISH version 3.0. Note of principle ". Note intern EDF No. H-I86-2004-00741-FR.

[Bib.2] C. Hervouet (2008). "Modifications made to the software CRAYFISH version 3.1 to obtain CRAYFISH version 3.1.1.". Note intern EDF No. H-I81-2008-03647-FR.

[Bib.3] C. Hervouet (2009). "Simulation of air/water flow/vapor through a crack: software CRAYFISH version 3.1.1 User's manual". Note intern EDF No H-I81-2009-00243-FR.

[Bib.4] C. Hervouet (2016). "Modifications made to the software CRAYFISH version 3.2.1 to obtain CRAYFISH version 3.2.2.". Note interns EDF No H-I8B-2016-00390-FR.

[Bib.5] C. Hervouet (2016). "Simulation in 1D of flow through a crack: software CRAYFISH version 3.2.2. User's manual". Note interns EDF No H-I8B-2016-00399-FR.

[Bib.6] U. Greiner, W. RAM (1995). "Air leakage characteristics in cracked concrete", Nuclear Engineering and Design, Volume 156, Issue 1, Pages 167-172.

7 Appendices

7.1 Syntax of the procedure CALC_ECREVISSE

```
CALC_ECREVISSE =
            (
# OUTGOING CONCEPT
            ♦ CHARGE_MECA     = CO ('char_meca')
[CO]
            ♦ CHARGE_THER1    = CO ('char_ther')
[CO]
            ♦ CHARGE_THER2    = CO ('char_ther')
[CO]
            ♦ TABLE           = CO ('table')                    [CO]
            ♦ FLOW            = CO ('flow')                     [CO]

# MODEL MECHANICAL
            ♦ MODELE_MECA     = m_meca                       [model]
            ♦ MODELE_THER     = m_ther                       [model]

# GIVEN GEOMETRICAL RELATING TO THE RESULTS
            ♦ RESULT    = _F (
                  ♦ MECHANICAL      = rmeca
[result]
                  ♦ THERMAL   = rther                        [result]
                  /     ◊ NUME_ORDRE = nume_ordre                  [I]
                        ◊ INST       = urgent                      [R]
                        ),
# GIVEN GEOMETRICAL RELATING TO THE CRACK
            ♦ CRACK     = _F (
                  ♦ GROUP_MA          = gma                  [grma]
                  ♦ GROUP_NO_ORIG     = ogno                 [grno]
                  ♦ GROUP_NO_EXTR     = egno                 [grno]
                  ♦ ZETA              = zeta                       [R]
                  ♦ ROUGHNESS         = rug                        [R]
                  ♦ OUVERT_REMANENTE = ouv_rem                     [R]
                  ◊ PREFIXE_FICHIER  =    / 'FISSURE1',       [DEFECT]
                                          /prefix
                  ◊ TORTUOSITY        = wrong                      [R]
                  ♦ SECTION           =    / "ELLIPSE"
                                          / "RIGHT-ANGLED"
                  ◊ LISTE_COTES_BL   =    / (0, max (abs_curv))   [DEFECT]
                                          / lcbl                  [listr8]
                  ♦ LISTE_VAL_BL    = lvbl                        [listr8]
                        ),

# RELATIVE DATA WITH THE FLOW
            ♦ FLOW      =… idem MACR_ECREVISSE/ECOULEMENT

            ♦ MODELE_ECRE     =… idem MACR_ECREVISSE/MODELE_ECRE

# RELATIVE DATA WITH DIGITAL CONVERGENCE
            ◊ CONVERGENCE_ECREVISSE  =…
                  idem MACR_ECREVISSE/CONVERGENCE_ECREVISSE
# GENERAL
            CURVES, SOFTWARE, VERSION…    =…
                  idem MACR_ECREVISSE/GENERAL
```

```
            ◊    INFORMATION    =    / 1
    [DEFECT]
                                     / 2
        )
```

7.2 Operands specific to CALC_ECREVISSE

7.2.1 Operand CHARGE_MECA

Outgoing concept containing the mechanical loading provided by Crayfish.

7.2.2 Operands CHARG_THER1 and CHARG_THER2

Outgoing concepts containing the thermal loadings provided by Crayfish.

7.2.3 Keyword RESULT

7.2.3.1 Operand MECHANICS

The result contains of STAT_NON_LINE

7.2.3.2 Operand THERMICS

The result contains of THER_LINEAIRE

7.2.3.3 Operand NUME_ORDRE

Sequence number of the step of computing time in progress.

7.2.3.4 Operand INST

Value of the moment (in seconds) of the step of computing time in progress.

7.3 Syntax of the procedure MACR_ECRE_CALC

```
MACR_ECRE_CALC =
      (
# OUTGOING CONCEPT
           ♦ TABLE     = CO ('table')                            [CO]
           ♦ FLOW      = CO ('flow')                             [CO]

# GIVEN GEOMETRICAL RELATING TO THE CRACK
           ♦ CRACK     = _F (
                 ♦ LENGTH          = long                        [R]
                 ♦ ROUGHNESS       = rug                         [R]
                 ♦ ANGLE           = alpha                       [R]
                 ♦ ZETA            = zeta                        [R]
                 ♦ SECTION         =/"ELLIPSE"
                                    / "RIGHT-ANGLED"
                 ♦ LISTE_COTES_BL  = lcbl                  [listr8]
                 ♦ LISTE_VAL_BL    = lvbl                  [listr8]
                 ♦ LISTE_COTES_AH  = lcah                  [listr8]
                 ♦ LISTE_VAL_AH    = lvah                  [listr8]
                           ),

# RELATIVE DATA WITH THE FLOW
           ♦ FLOW      = idem MACR_ECREVISSE/ECOULEMENT

# RELATIVE DATA WITH THE PROFILE OF TEMPERATURE THROUGH THE WALL
           ◊ TEMPERATURE     = _F (
                 / ♦ GRADIENT            =     "PROVIDED"
                   ♦ LISTE_COTES_TEMP    =     lct               [R]
                   ♦ LISTE_VAL_TEMP      =     lvt               [R]
                 / ♦ GRADIENT            =     "IMPOSES"
                   ♦ TEMP1               =     tm1               [R]
                   ♦ TEMP2               =     tm2               [R]
                 / ♦ GRADIENT            =     "CALCULATES"
                   ♦ EPAISSEUR_PAROI     =     epp               [R]
                   ♦ CONVECTION_AMONT    =     alphe             [R]
                   ♦ CONVECTION_AVAL     =     alphs             [R]
                   AVERAGE ♦             =     lambd             [R]
                   ♦ TEMP_FLUIDE_AVAL    =     ts                [R]
                              ),

# RELATIVE DATA WITH THE FLOW
           ♦ FLOW      =… idem MACR_ECREVISSE/ECOULEMENT

           ♦ MODELE_ECRE     =… idem MACR_ECREVISSE/MODELE_ECRE

# RELATIVE DATA WITH DIGITAL CONVERGENCE
           ◊ CONVERGENCE_ECREVISSE   =… idem
           MACR_ECREVISSE/CONVERGENCE_ECREVISSE
# GENERAL
           CURVES, SOFTWARE, VERSION…    =     … idem
MACR_ECREVISSE/GENERAL
      )
```

7.4 Operands specific to MACR_ECRE_CALC

7.4.1 Keyword CRACK

7.4.1.1 Operand **ANGLE**

Angle of the flow compared to the ascending vertical (degrees).

7.4.1.2 Operand **LENGTH**

The real length of the crack defines (taking account of its tortuosity)

7.4.1.3 Operand **LISTE_COTES_AH**

`LISTE_COTES_AH` allows to inform the curvilinear X-coordinates where dimension D is givenU main roads DE the crack.

7.4.1.4 Operand **LISTE_VAL_AH**

`LISTE_VALLEY_AH` allows to inform them values of main roads DE section of the crack/ conduit. According to the value of the operand `SECTION` :
- `ELLIPSE` : List of the values of the points defining the main roads of the section;
- `RECTANGLE` : List of the values of the points defining the length of the section.

7.4.2 Keyword **TEMPERATURE**

7.4.2.1 Operand **GRADIENT**

Model of the variation in temperature:
- Provided: Distribution of provided temperature;
- Imposed: Imposed distribution of temperature;
- Calculated: Profile of temperature calculated;

7.4.2.2 Operand **LISTE_COTES_TEMP**

List of the dimensions for the temperatures.

7.4.2.3 Operand **LISTE_VAL_TEMP**

List of the values of temperature.

7.4.2.4 Operand **TEMP1**

Variation in temperature of the wall along the flow.

7.4.2.5 Operand **TEMP2**

Temperature of the wall at the entry.

7.4.2.6 Operand **EPAISSEUR_PAROI**

Thickness of the wall.

7.4.2.7 Operand **CONVECTION_AMONT**

Convection coefficient on the surface of the wall with dimensions upstream.

7.4.2.8 Operand **CONVECTION_AVAL**

Convection coefficient on the surface of the wall with dimensions downstream.

7.4.2.9 Operand **LAMBDA**

Thermal conduction of the wall.

7.4.2.10 Operand **TEMP_FLUIDE_AVAL**

Temperature of the fluid with dimensions downstream.