ZZZZ218 – Summarized validation of the command

MACR_ECREVISSE:

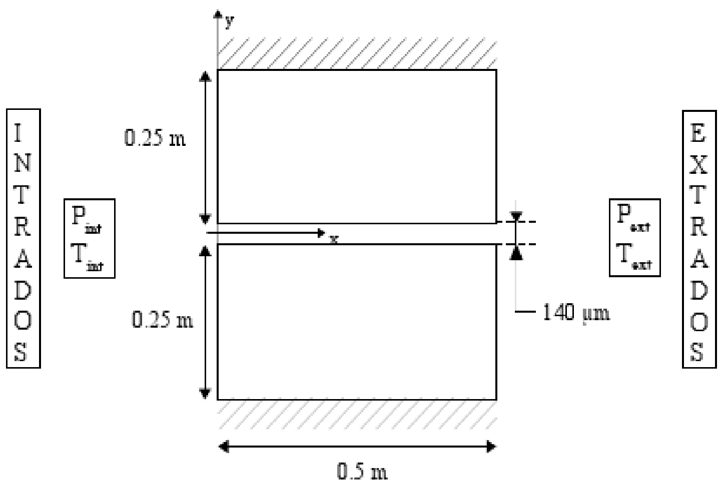
This benchmark makes it possible to validate by means of computer the sequence of Code_Aster with Ecrevisse, realized via macro-command `MACR_ECREVISSE`, to estimate the flows of fluid (air/water/vapor) which can cross a crack.
Three modelizations are proposed, whose first and second are of NON-regression. In the first modelization, there is a horizontal crack in a structure; in the second, there are 2 vertical cracks which interact; in the third, one tests the macro-command compared to a rotation-translation.

1 Problem of reference

This test is inspired by test SIMIBE carried out at the French atomic energy agency.
Three different modelizations are described. The material and the characteristic of flow are the same ones for the three modelizations, and they are described in the section §1. The geometry changes slightly for the three modelizations. One A shows in the §1.1 a diagram of the geometry for the modelization; for the other modelizations one goes will describe the differences.

1.1 Geometry and material

the total geometry is presented on Appear 1.1-a. The characteristics of crack are given in bottom. To notice that the unit are expressed in system international S.I. As also specified in the user's documentation U7.03.41, that is made compulsory by the software *Crayfish*, which contains not adimensionalized formulas.



Appear 1.1-a : geometry of the Details

benchmark of crack:
• section: RECTANGLE
• direction of flow: X , in the positive meaning
• absolute roughness of the wall: $0,5.10^{-6} m$
• loss ratio of singular load at the entry: no (ZETA = 0)
• dimension of crack in the normal direction with the plane (z): $0.5 m$ (LISTE_VAL_BL = (0.5, 0.5))
•remanent opening fixed at $30 \mu m$

Flow:
• stagnation pressure at the entry: $10.10^5 Pa$
• stagnation pressure at the exit: $10^5 Pa$
• condition of the fluid at the entry: air alone (FLUIDE_ENTREE = 6)
•temperature at the entry: $140°C$

Model:
•model flow with SATURATION
•friction calculated directly from the absolute roughness of the wall (FROTTEMENT = 1)
•heat transfer with a correlation of Sieder & Touches into monophasic laminar and a correlation of Mac Adams in the other modes. In the event of gas mixture/liquidates, computation either in gas, or in the fluid, or via the correlation of Chen according to the mass title of gas and the rate of vacuum (TRANSFERT_CHAL = 1).

1.2 Properties of the material

the selected values are representative of a concrete.

$E = 35\,000\,MPa$

$\nu = 0.25$

$\alpha = 10-5/°C$

$\lambda = 2.3\,J/m^2 s\,°C/m$

$\rho C_p = 2500000\,J/m^3\,°C$

1.3 Boundary conditions and loading

the parts higher and lower are clamped.
It is supposed that the crack cannot be entirely closed. Thus, the remanent opening is fixed at $30\,\mu m$ to leave a non-zero minimum fluid flow.
With the suction face, the temperature is always worth $T_{ext} = 20\,°C$ and the pressure $P_{ext} = 1.105\,Pa$.
On the sides internal and external, one supposes that the exchanges with the ambient conditions take place with the coefficients of heat exchange according to: $h_{int} = 8\mathrm{W}/m^2$ and $h_{ext} = 4\mathrm{W}/m^2$
One injects hot air under pressure is $T_{int} = 140\,°C$ and $P_{int} = 10.10^5\,Pa$.

1.4 Initial conditions

the concrete is at rest, with $20\,°C$, with a crossing crack of $140\,\mu m$ opening.

2 Reference solution

the modelizations A and B are test of non regression.

The modelization C the behavior of the macro-command for an oblique crack checks, and that the macro one is robust compared to a rotation-translation. The response of structure with a position of reference is compared with that of same turned and relocated structure.

3 Modelization A

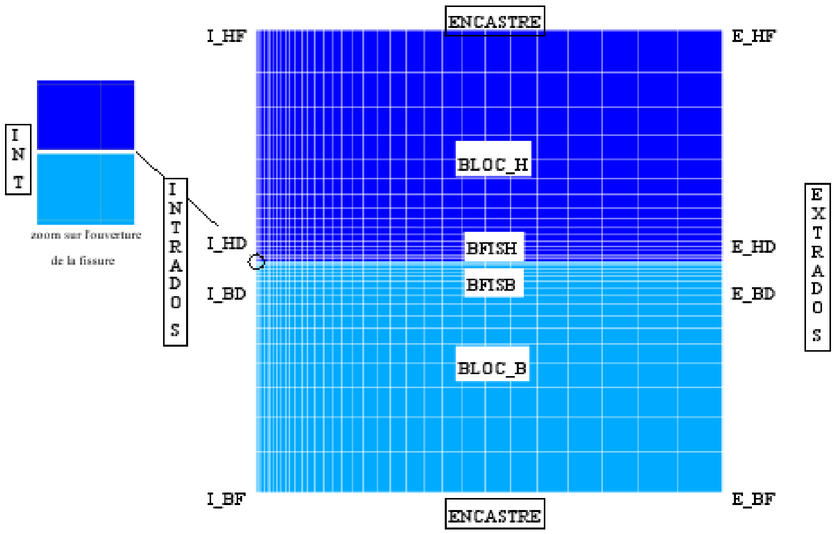
3.1 Characteristic of the modelization

One validates here behavior of the command MACR_ECREVISSE in the presence of a crossing crack horizontal. One chooses a modelization in plane strains for mechanics D_PLAN, and a thermal modelization PLAN_DIAG, with a diagonalized mass matrix for the thermal.

The characteristics of flow have summers described with the geometry with the §1.1.

3.2 Characteristics of the mesh

The mesh used is presented Appear 3.2-a :



Appear 3.2-a : Complete mesh

dimensions are the same ones as for the geometry.

Many nodes: 1260
Number of meshes: 1156 QUAD4

the parameters of growth used to carry out the mesh is the following: of $0.002\,m$ (underside) to $0.05\,m$ (suction face), and idem of BFISH and BFISB with ENCASTRE.

3.3 Quantities and results

One tests the significant quantities of this computation namely: flow, as well as the displacement and the temperature as starter and in crack output. Two times are tested.

A: $t=500\,s$

Identification	Tolerance
Displacement DY with the node E_{HD} $[m]$	1.0E-06
Temperature of the material to the node E_{HD} $[°C]$	1.0E-06
Displacement DY with the node I_{HD} $[m]$	1.0E-06
Temperature with the node I_{HD} $[°C]$	1.0E-06
Flow	1.0E-06

a: $t=10\,000\,s$

Identification	Tolerance
Displacement DY with the node E_{HD} $[m]$	1.0E-06
Temperature of the material to the node E_{HD} $[°C]$	1.0E-06
Displacement DY with the node I_{HD} $[m]$	1.0E-06
Temperature with the node I_{HD} $[°C]$	1.0E-06
Flow	1.0E-06

3.4 Remarks

A $t=10000\,s$, node `I_HD` moved approximately $-70\,\mu m$, (in particular because of thermal thermal expansion) what corresponds to the half opening of crack. That means that the lips are in contact (activated `key word` DEFI_CONTACT) and fissures it closed. On the other hand, for the hydraulic part (managed by *Crayfish*), a remanent opening is fixed, so that the flow is never null.

4 Modelization B

4.1 Characteristic of the modelization

In this modelization, one validates the use of macro-command MACR_ECREVISSE in the presence of 2 vertical cracks. The geometry is slightly different from that of modelization A. It is described with the mesh in Figure 4.2-a : 4.2-a. The characteristics of flow and the material have summers described with the § 1.

As for the modelization A, one works in plane strains for the mechanics (D_PLAN), and with a diagonalized mass matrix for thermal (PLAN_DIAG).

4.2 Mesh and boundary conditions

The mesh used are presented Figure 4.2-a : 4.2-a :

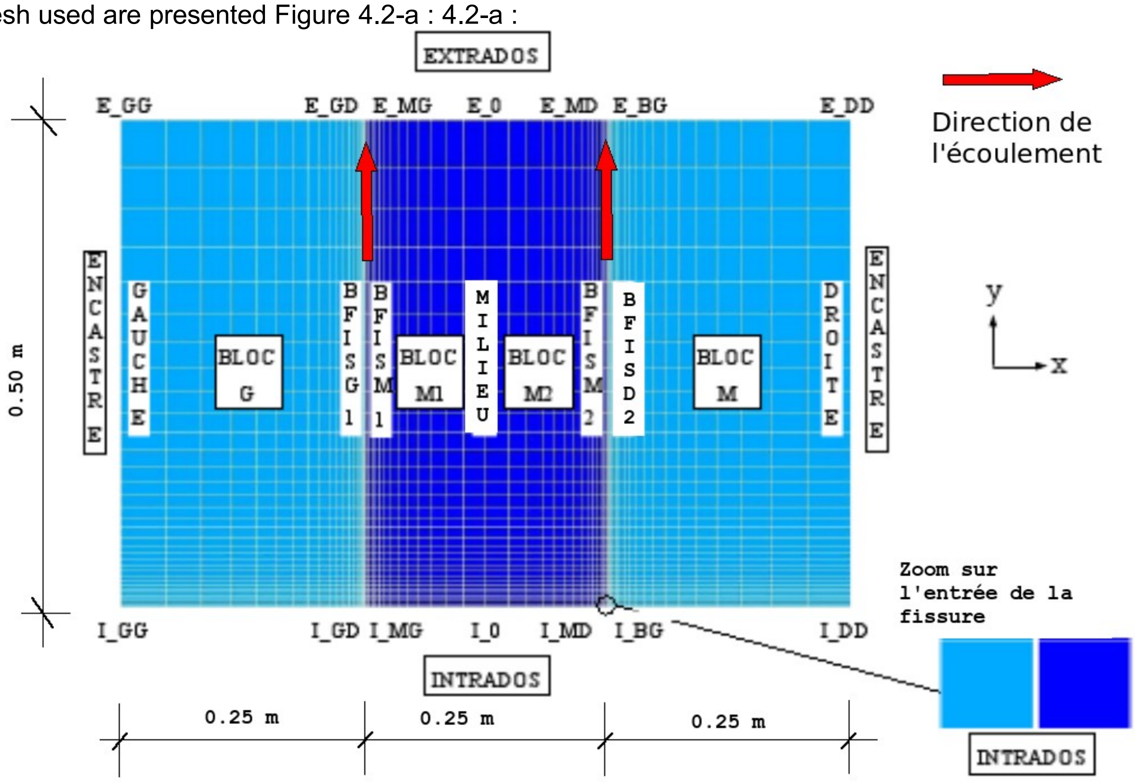


Figure 4.2-a : 4.2-a Complete mesh

dimensions of each of the three blocks are $0.50\,m$ top and $0.25\,m$ broad.

Many nodes: 2275
Number of meshes: 2108 QUAD4

the parameters of growth of the sizes of meshes used to carry out the mesh are the following: of $0.002\,m$ (underside) to $0.05\,m$ (suction face), and idem of BFISG1/BFISD2 with ENCASTRE; of $0.025\,m$ to the MILIEU with $0.002\,m$ on BFISM1/BFISM2.
The cracks are called with the name of the lips: BFISG1-BFISM1 (CRACK 1), (CRACK 2).

Boundary conditions:

1. With dimensions named the ENCASTRE are clamped ($DX=0$, $DY=0$).
2. On with dimensions the MILIEU (line of symmetry) one block displacement in direction X ($DX=0$).
3. A condition of contact is defined between lips BFISG1-BFISM1 and BFISM2-BFISD2 (DEFI_CONTACT).
4. The pressure and the temperature on the underside UNDERSIDE are larger than on the suction face SUCTION FACE ($1.\mathrm{E}6\,Pa$ and $140\,°C$ versus $1.\mathrm{E}6\,Pa$ and $20\,°C$), which causes the flow of the underside to the suction face.
5. The material is considered, at the beginning of computation, with the temperature environment $20\,°C$, which is the reference temperature.

4.3 Quantities and results

One tests at 2 different times, displacements and the temperature as starter of crack of left and in output of crack of right. Lastly, one tests the flow of crack of right to $t=500\,s$ and of crack of left with $t=10\,000\,s$.

A: $t=500\,s$

Identification	Tolerance
Displacement DX with the node E_{MD} $[m]$	1.0E-06
Temperature of the material to the node E_{MD} $[°C]$	1.0E-06
Displacement DX node I_{GD} $[m]$	1.0E-06
Temperature of the material to the node I_{GD} $[°C]$	1.0E-06
Crack BFISG1-BFISM1, flow	1.0E-06

a: $t=10\,000\,s$

Identification	Tolerance
Displacement DX with the node E_{MD} $[m]$	1.0E-06
Temperature of the material to the node E_{MD} $[°C]$	1.0E-06
Displacement DX with the node I_{GD} $[m]$	1.0E-06
Temperature of the material to the node I_{GD} $[°C]$	1.0E-06
Crack BFISM2-BFISD2, flow	1.0E-06

4.4 Remarks

the opening of crack with $t=10\,000\,s$ is about 10^{-9} , therefore is almost closed because of thermal thermal expansion due to the high temperature with the underside. In this case also, it is the remanent opening which is retained for the computation of flow.

5 Modelization C

5.1 Characteristic of the modelization

In this modelization, one validates the use of macro-command MACR_ECREVISSE compared has a rotation and with a translation. It is not thus about a test of NON-regression.
Indeed, the results of *Crayfish* depend only on the characteristics of crack, including the direction. This one is influenced by gravity. Thus, cracks with same the characteristics and having a symmetric direction compared to the vertical must give same flows.
One works with the same parameters (of the material, of the flow of crack) that in the modelization A (§ 1.1). The mesh is also the same one, except that it is turned and relocated. The detail of the mesh is given to the §5.2.

5.2 Mesh and boundary conditions.

The two meshes used were obtained by rotation and translation of the mesh of the modelization A, therefore they preserve same dimensions of them. They are presented in Figure 5.2-a : 5.2-a and Figure 5.2-b : 5.2-b.

For the first mesh, the first curvilinear abscisse of crack is the point of origin of the axes $(0;0)$.
The second mesh results from a rotation of 120 degrees of the first mesh around the origin and from a translation of vector $(-10;20)$.

The boundary conditions for the two meshes similar to modelization a:

1. with dimensions are named the FIXE1 (or FIXE2) are clamped ($DX=0$, $DY=0$).
2. A condition of contact is defined between lips BFISH1-BFISB1 (BFISH2-BFISB2) (DEFI_CONTACT).
3. The pressure and the temperature on underside INTRA1 (INTRA2) are larger than on suction face EXTRA1 (EXTRA2) : ($1.E6\,Pa$ and $140°C$ versus P_{atm} and $20°C$). That causes the flow of the underside to the suction face.
4. The material is considered, at the beginning of computation, with the room temperature $20°C$, which is the reference temperature.

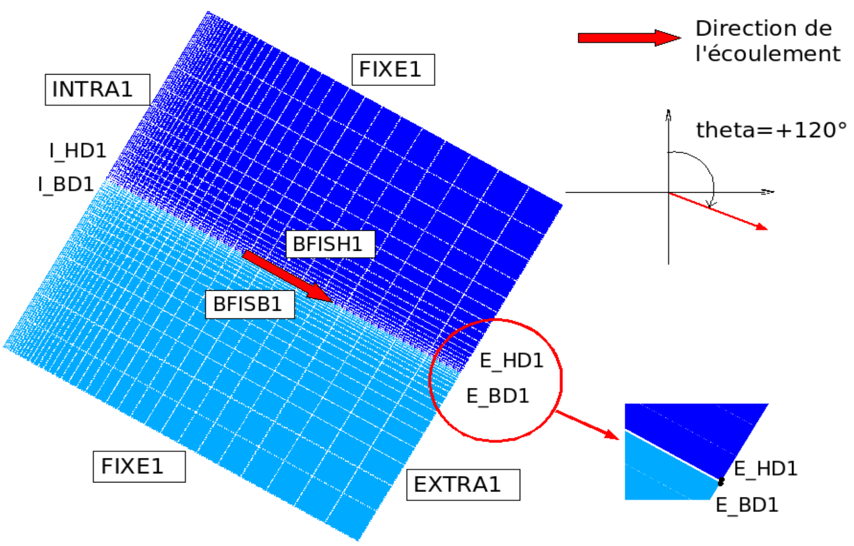


Figure 5.2-a : 5.2-a Mesh 1 for the direction $theta=120°$ **(compared to the vertical).**

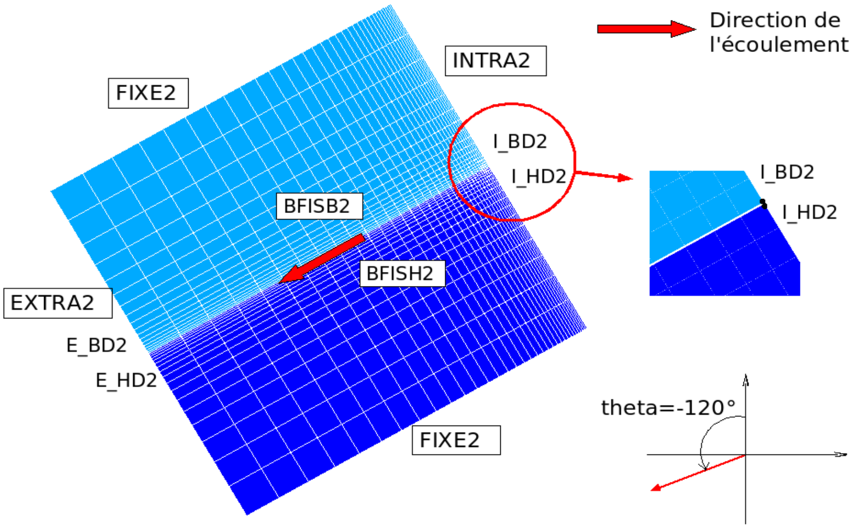


Figure 5.2-b : 5.2-b Mesh 2 for the direction $theta=-120°$ **(compared to the vertical).**

5.3 Quantities tested and results

One tests the results at time $t=10\,000\,s$. One extracts the values from result of the mesh 2, and one compared to those corresponding them to mesh 1.

Mesh 1	**Mesh 2**
Displacement DX with the node E_{HD1}	by symmetry: (- 1) * Displacement DX with the node E_{BD2}
Displacement DX with the node E_{BD1}	by symmetry: (- 1) * Displacement DX with the node E_{HD2}
Displacement DY with the node E_{HD1}	by symmetry: Displacement DY with the node E_{BD2}
Displacement DY with the node E_{BD1}	by symmetry: Displacement DY with the node E_{HD2}
Temperature of the material to the node I_{HD1}	Temperature of the material to the node I_{HD2}
total Flow	total Flow
Coefficient Convection first ab. curv.	Coefficient Convection first ab. curv.
Pressure first ab. curv.	Pressure first ab. curv.
Temperature of the fluid first ab. curv.	Temperature of the fluid first ab. curv.
Heat flux of the fluid first ab. curv.	Heat flux of the fluid first ab. curv.

Quantity	**Tolerance**

Displacement DX with the node E_{HD1}	1.0E-05
Displacement DX with the node E_{BD1}	1.0E-05
Displacement DY with the node E_{HD1}	1.0E-05
Displacement DY with the node E_{BD1}	1.0E-05
Temperature of the material to the node I_{HD1}	1.0E-04
total Flow	1.0E-03
Coefficient Convection first ab. curv.	1.0E-04
Pressure first ab. curv.	1.0E-04
Temperature of the fluid first ab. curv.	1.0E-04
Heat flux of the fluid first ab. curv.	1.0E-03

5.4 Remarks

the lips are in contact, command `DEFI_CONTACT` is activated. The computation of flow is carried out with the remanent opening.

6 Summary of the results

the results are coherent with it what physically one expected.