WTNP127 – Modelization of a flow of water in a saturated bar, establishment of a Summarized permanent

mode:

This benchmark represents the modelization of a flow of water in a bar subjected to a gradient of pressure. One models here a diphasic flow which one makes degenerate into a monophasic problem. We are interested in this benchmark in the establishment of the permanent mode which makes it possible analytically to calculate water flux in output. This benchmark has as a main objective to validate the computation of the integral of hydraulic flux on a surface.

1 Problem of reference

the purpose of this benchmark is to test the computation of the integral of flux on a surface.

1.1 Geometry

One considers a bar 5m length and 1m top.

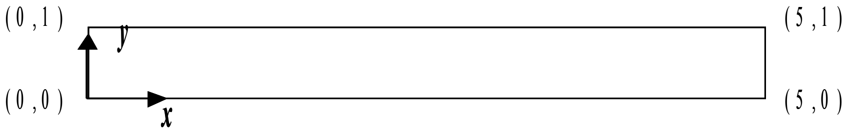

Illustration 1: : Geometry

1.2 Properties of the materials

One gives here only the properties whose solution depends, knowing that the command file contains other data of material which do not play any part in the solution of with the dealt problem.

Relative	Permeability Viscosity	1
	liquidates $\mu(\ pa.s)$	1
	Modulates compressibility	0
	Density of the fluid $\rho\ (\ kg/m^3)$	1
homogenized Parameters	intrinsic Permeability $\text{K\_int}(m^2)$	10^{-13}
	Porosity	$0{,}5$
	Storage	10^{-10}
	Saturation out of fluid	1
	Henry $(Pa.mol^{-1}.m^3)$	10^{10}

Table 1.2-1 : Properties of the materials

1.3 Boundary conditions and initial

the boundary conditions are conditions of Dirichlet:

On the left part of the field, $P_l(t,x=0,y)=0\,Pa$

On the right part of the field, $P_l(t,x=L,y)=10^4\,Pa$

the initial fluid pressure is of $P_l(t=0,x,y)=10^4\,Pa$.

1.4 Lasted of simulation and time step

the period of simulation is of $50000\,s$ and the number of time step is of 5.

2 Reference solution

2.1 Method of calculating

Is a bar saturated with water (regarded as incompressible). This bar length L and height h has an initial pressure $P_l(x,y,t=0)=P_{ini}$ and is subjected to a gradient of pressure such as $P_l(0,y,t)=P_G$ and $P_l(L,y,t)=P_{ini}$.

This problem of evolution led at the end of a time t_p to a linear permanent state such as $P(x,y,t>t_p)=\frac{P_{ini}-P_G}{L}x+P_G$

water flux $\boldsymbol{M}_{11}$ (factor of the gradient of pressure) is then constant along the bar. If one integrates it on a vertical cut Γ of the bar, and outgoing norm $\boldsymbol{\nu}$, one obtains:

$$\int_{\Gamma}\boldsymbol{M}_{11}.\boldsymbol{\nu}=h.\rho_l\frac{K_{int}}{\mu_l}.\frac{P_G-P_{ini}}{L}.\boldsymbol{x}.\boldsymbol{\nu}$$

The computation of this integral will be realized in this benchmark on 3 surfaces (or side in $2\mathrm{D}$).

2.2 Simplifying assumptions

In order to test the computation of the flux on the model hydraulic most complete possible, one starts from a diphasic modelization which one makes degenerate into monophasic modelization. For that, it is considered that the medium is completely saturated with water and one imposes a gas pressure null on all the nodes. The biphasic system is then brought back to solve the following problem:

$$\frac{\partial(\varphi\rho_l)}{\partial t}-div(K_{int}\frac{\rho_l k_{rl}}{\mu_l}\nabla P_l)=0$$

•The fluid is incompressible: $\rho_l=cst$

•The matrix is compressible and porosity evolves proportionally with the fluid pressure: $\frac{\partial\varphi}{\partial P_l}=E_m$

•The relative permeability is taken equalizes to 1: $k_{rl}=1$

The conservation equation of the mass for the fluid is thus written:

$$\rho_l E_m\frac{\partial P_l}{\partial t}-div(K_{int}\frac{\rho_l}{\mu_l}\nabla P_l)=0$$

A really saturated modelization will be also tested (modelization D).

2.3 Uncertainties on the solution

uncertainties are null, because the reference solution is analytical.

3 Modelization A

3.1 Characteristic of the modelization

One models a case here $2D$. The flux are calculated on 3 sides:

- the left vertical side, noted "MGAUCHE"
- the vertical side right, noted "MDROIT"
- a vertical side in the matter, noted "MILLET".

One will reorientate meshes edge in order to have an outgoing norm. The flux being directed line towards the left in this example will be positive on MGAUCHE and negative on MDROIT.

MILLET will be reorientated so that the norm is outgoing with the right part of the bar leaning on MILLET. In this way, the flux will be positive on MILLET.

To reorientate meshes in $2D$, one uses factor key word ORIE_PEAU_2D of the command MODI_MAILLAGE. If the side is internal, it is necessary to specify a mesh group surface on which it rests to determine the outgoing norm with this group (key word GROUP_MA_SURF).

To reorientate meshes in $3D$, one uses factor key word ORIE_PEAU_3D of the command MODI_MAILLAGE. If surface is internal, it is necessary to specify a mesh group voluminal on which it rests to determine the outgoing norm with this group (key word GROUP_MA_VOLU).

The quantity of water on surfaces Γ thus defined will be thus equal to

$$\int_\Gamma \boldsymbol{M}_{11} . \boldsymbol{\nu} = h . \rho \frac{K_{int}}{\mu} . \frac{P_{ini} - P_G}{L} = 2\,10^{-10} kg.s^{-1} .$$

The flux of vapor $\boldsymbol{M}_{12}$, dry air $\boldsymbol{M}_{21}$ and dissolved air $\boldsymbol{M}_{22}$ are them almost null (with simplifications near).

The modelization tested here is D_PLAN_HH2S

3.2 Characteristics of the mesh

Many nodes: 805
Number of meshes and types: 406 meshes, 206 SEG3 and 200 QUAD8

3.3 Quantities tested and Standard

Identification	results of reference	Value	Tolerance (%)
Component $INTE\_FH11$, place $MDROITE$	"AUTRE_ASTER"	-2.0E-10	0,1%
Component $INTE\_FH11$, place $MMIL$	"AUTRE_ASTER"	2.0E-10	0,1%
Component $INTE\_FH11$, place $MGAUCHE$	"AUTRE_ASTER"	2.0E-10	0,1%

One of the mesh test hydraulic flux at the first Gauss point M_{401} at the sequence number 5:

Standard	identification of reference	Value	Tolerance (%)
Component $FH11$	"NON_REGRESSION"	2.00133E-10	0,1%
Component $FH22$	"NON_REGRESSION"	1.99933E-11	0,1%

4 Modelization B

4.1 Characteristic of the modelization

Even case that previously but in of axisymmetric. The expected results are different because of integration:

$$\int_{\Gamma} \boldsymbol{M}_{11}.\boldsymbol{\nu}=\boldsymbol{M}_{11}.\boldsymbol{\nu}\int_0^1\int_0^1 r\,dr\,d\theta=0.5\,\boldsymbol{M}_{11}.\boldsymbol{\nu}$$

The modelization used is `AXIS_HH2S`.

4.2 Characteristics of the mesh

Many nodes: 805
Number of meshes and types: 406 meshes, 206 `SEG3` and 200 `QUAD8`

4.3 Quantities tested and Standard

Identification	results of reference	Value	Tolerance (%)
Component $INTE\_FH11$, place $MDROITE$	"AUTRE_ASTER"	-1.0E-10	0,1%
Component $INTE\_FH11$, place $MMIL$	"AUTRE_ASTER"	1.0E-10	0,1%
Component $INTE\_FH11$, place $MGAUCHE$	"AUTRE_ASTER"	1.0E-10	0,1%

One of the mesh test hydraulic flux at the first Gauss point M_{401} at the sequence number 5:

Standard	identification of reference	Value	Tolerance (%)
Component $FH11$	"NON_REGRESSION"	2.00136E-10	0,1%
Component $FH22$	"NON_REGRESSION"	0.	0,1%

5 Modelization C

5.1 Characteristic of the modelization

Even case that the modelization A but in of $3D$. The expected results are the same ones.
The modelization used is 3D_HH2S.

5.2 Characteristics of the mesh

Many nodes: 1913
Number of meshes and types: 206 meshes, 200 HEXA20 and 6 QUAD8

5.3 Quantities tested and Standard

Identification	results of reference	Value	Tolerance (%)
Component $INTE\_FH11$, place $MDROITE$	"AUTRE_ASTER"	-2.0E-10	0,1%
Component $INTE\_FH11$, place $MMIL$	"AUTRE_ASTER"	2.0E-10	0,1%
Component $INTE\_FH11$, place $MGAUCHE$	"AUTRE_ASTER"	2.0E-10	0,1%

One of the mesh test hydraulic flux at the first Gauss point M_{401} at the sequence number 5:

Standard	identification of reference	Value	Tolerance (%)
Component $FH11$	"NON_REGRESSION"	2.00133E-10	0,1%
Component $FH22$	"NON_REGRESSION"	1.99933E-11	0,1%

6 Modelization D

6.1 Characteristic of the modelization

Even case that the modelization A but in D_PLAN_HMS (really saturated modelization, the gas flux do not exist any more). The mesh consists of triangles.

The expected results are the same ones.

6.2 Characteristics of the mesh

Many nodes: 625
Number of meshes and types: 344 meshes, 60 SEG3 and 284 TRIA6

6.3 Quantities tested and Standard

Identification	**results of reference**	**Value**	**Tolerance ($\%$)**
Component $INTE\_FH11$, place $MDROITE$	"AUTRE_ASTER"	-2.0E-10	0,1%
Component $INTE\_FH11$, place $MMIL$	"AUTRE_ASTER"	2.0E-10	0,1%
Component $INTE\_FH11$, place $MGAUCHE$	"AUTRE_ASTER"	2.0E-10	0,1%

7 Modelization E

7.1 Characteristic of the modelization

Even case that the preceding modelization but in D_PLAN_HS (really saturated modelization, the gas flux do not exist any more). The mesh consists of triangles.
In addition, instead of applying a gradient of pressure, one directly applies flux expected in output (the purpose of that is testing the condition in water flux limit for modelization D_PLAN_HS.).
The expected results are the same ones.

7.2 Characteristics of the mesh

Many nodes: 625
Number of meshes and types: 344 meshes, 60 SEG3 and 284 TRIA6

7.3 Quantities tested and Standard

Identification	**results of reference**	**Value**	**Tolerance (%)**
Component $INTE\_FH11$, place $MDROITE$	"AUTRE_ASTER"	-2.0E-10	0,1%
Component $INTE\_FH11$, place $MMIL$	"AUTRE_ASTER"	2.0E-10	0,1%
Component $INTE\_FH11$, place $MGAUCHE$	"AUTRE_ASTER"	2.0E-10	0,1%

8 Modelization F

8.1 Characteristic of the modelization

Even case that the modelization D but in D_PLAN_HM_SI (really saturated under-integrated modelization, gas flux do not exist any more). The mesh consists of triangles.

The expected results are the same ones.

8.2 Characteristics of the mesh

Many nodes: 625
Number of meshes and types: 344 meshes, 60 SEG3 and 284 TRIA6

8.3 Quantities tested and Standard

Identification	results of reference	Value	Tolerance (%)
Component $INTE\_FH11$, place $MDROITE$	"AUTRE_ASTER"	-2.0E-10	0,1%
Component $INTE\_FH11$, place $MMIL$	"AUTRE_ASTER"	2.0E-10	0,1%
Component $INTE\_FH11$, place $MGAUCHE$	"AUTRE_ASTER"	2.0E-10	0,1%

9 Synthesis

One models in this benchmark the establishment of a permanent mode for a flow of water in a bar. One validates the computation of the integral of hydraulic flux on a surface that it is of edge or intern to the field. The validation is made in $2D$ and in $3D$. In all the cases, the got results correspond well to the analytical solution