WTNP117 – Capillary rebalancing of bi--materials describes by laws of Van-Genuchten Mualem

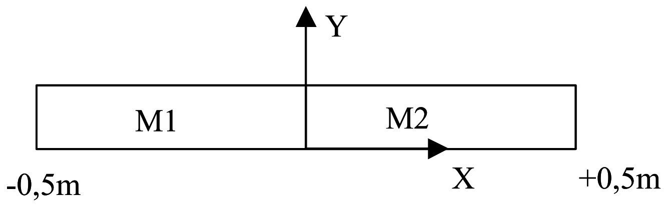
Summary:

The test presented makes it possible to simulate a case of resaturation of a material by another, the 2 materials being described by a model of Mualem Van-Genuchten. It is about a classical case of type BO-BG which enables us to test the hydraulic law called by `HYDR_VGM`. It also allows the comparison of several digital diagrams: finite elements and eccentric finished volumes.

1 Problem of reference

1.1 Geometry

The studied field is composed of two mediums of $0{,}5\,m$ each one.



The material $M1$ will be called worked barrier (BO) and the material $M2$ geological barrier (BG)

1.2 Properties of 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.

BO		
Liquid water	Density ($kg.m^{-3}$)	1000
	Viscosity	10^{-3}
Homogenized parameters	Permeability K	$10^{-20}\,m^2$
	Porosity	0.3
Parameters of Van-Genuchten	N	$1{,}064$
	Pr	$1{,}5\,Mpa$
	Sr	0
	$Smax$	$0{,}999$
Initial state	Pressure	$P_c^0=89\,MPa\,(S=0.77)$ $P_{gz}=1\,atm$

BG		
Liquid water	Density ($kg.m^{-3}$)	1000
	Viscosity	10^{-3}
Homogenized parameters	Permeability K	$10^{-19}\,m^2$
	Porosity	0.05

Parameters of Van-Genuchten	N	$1{,}7$
	Pr	$10\,Mpa$
	Sr	0
	$Smax$	$0{,}999$
Initial state	Pressure	$P_c^0=0(S=1.)$ $P_{gz}=1\,atm$

The curves of saturation and permeabilities obey the Mualem-Van-Genuchten model (HYDR_VGM). It is thus necessary to define in materials the parameters N , Pr , Sr , $Smax$.
It is pointed out that these models are:

$$S_{we}=\frac{S-S_{wr}}{1-S_{wr}} \text{ and } m=1-\frac{1}{n}$$

$$S_{we}=\frac{1}{\left[1+\left[\frac{P_c}{P_r}\right]^n\right]^m}$$

The permeability relating to water is expressed by integrating the model of prediction proposed by Mualem (1976) in the model of capillarity of Van Genuchten.

$$k_r^w=\sqrt{S_{we}}(1-(1-S_{we}^{1/m})^m)^2$$

The permeability to gas is formulated in a similar way:

$$k_r^w=\sqrt{(1-S_{we})}(1-S_{we}^{1/m})^{2m}$$

One recalls that for $S>Smax$, these curves are interpolated by a polynomial of degree 2 $C1$ in $Smax$.

1.3 Boundary conditions and initial

We are in boundary conditions: null flow everywhere (defect).

BG is saturated ($S=1$) and BO is partially désaturée ($S=0{,}77$). Into capillary term of pressure, that results in $Pc=0$ in BG and $Pc=89\,Mpa$ in the worked barrier.

1.4 Bibliographical references

1. Granet, S. (2006). Thermohydraulic case test on bi--materials: Comparison of various digital diagrams. Note HT-64-06-012.

2 Modeling A

2.1 Characteristics of modeling A

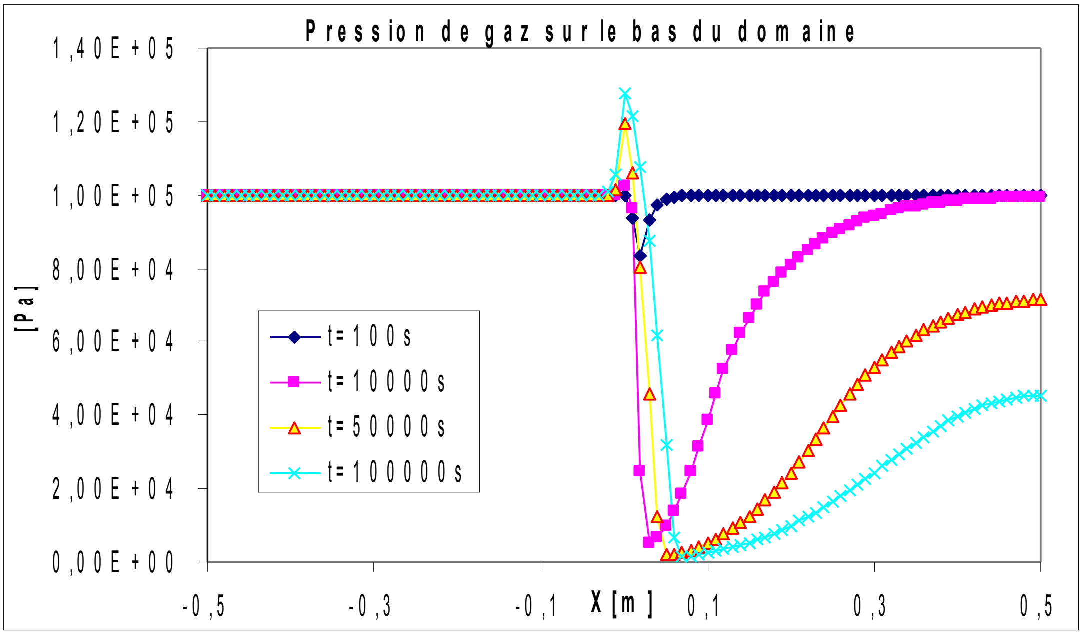
Modeling HHS in plane deformations. Coupling LIQU_GAZ. 100 elements QUAD8.

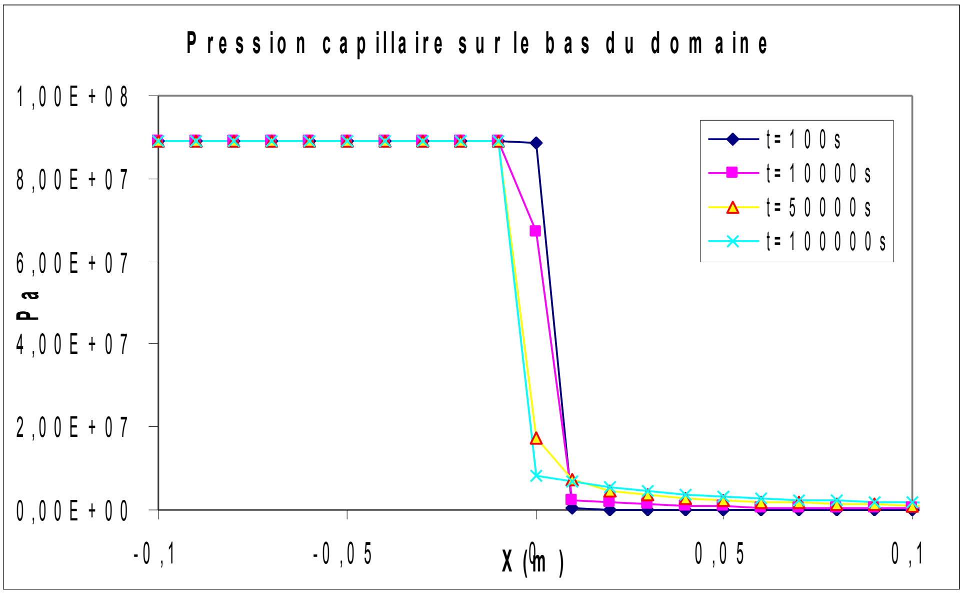
Discretization in time:

- $1000s$ in 20 pas de time
- $5000\,s$ in 20 pas de time
- $10000\,s$ in 10 pas de time
- $50000\,s$ in 20 pas de time
- $100000\,s$ in 20 pas de time

2.2 Results

The figures below present the profiles of gas pressures, capillary pressures and saturations along bi--materials at various times:





One observes well the desaturation of the geological barrier by the worked barrier. The profiles of gas pressure are also characteristic of this kind of problem: one observes a peak of gas pressure to the interface of the two materials which is with the fact that the gas is compressed by the water which resature the worked barrier. If the existence of this peak has a physical reality, its width is on the other hand due to a problem of digital diagram (known problem) as we will see it for modeling C.
The oscillations observed on saturations are also well-known (one will refer to [1]). The materials are indeed defined with the elements and not with the nodes. What means that on node located at the interface, 2 curves of capillary pressures are definite and different. This point explains why if the capillary continuity of pressure is assured it is not the same for saturation.

2.3 Values tested

This case test does not have a value of reference, one thus makes of them a case of nonregression. One carries out tests on two values:

X (m)	Time (s)	$PRE1$ **Aster**	**Authorized relative error**
0.03	5000	$7.5\,10^{5}$	1 %
0.03	100000	$4.48\,10^{6}$	1 %

3 Modeling B

3.1 Characteristics of modeling B

Modeling HHS in plane deformations. Coupling LIQU_VAPE_GAZ. 100 elements QUAD8.

In one the 2nd calculation, one tests the automatic management of the step of time.

Discretization in time:

- $1000s$ in 20 pas de time
- $5000\,s$ in 20 pas de time
- $10000\,s$ in 10 pas de time
- $50000\,s$ in 20 pas de time
- $100000\,s$ in 20 pas de time

With the automatic management of the step of time, one gives only the 1st step of times and the moment of passage obliged (for TEST_RESU):

- $50\,s$
- $5000\,s$
- $100000\,s$

The code manages itself the steps of time.

3.2 Results

The results are practically the same ones as for modeling A what is logical since there is no thermics.

The automatic management of the step of time makes it possible to make 5 times less step of time.

3.3 Values tested

One carries out 2 tests of nonregression for each calculation:

calculation n°1

X (m)	Time (s)	$PRE1$ Aster	Authorized relative error
0.03	5000	$7.5\,10^5$	$1\,\%$
0.03	100000	$4.48\,10^6$	$1\,\%$

calculation n°2 (automatic management of the list of moments)

X (m)	Time (s)	$PRE1$ Aster	Authorized relative error
0.03	5000	$7.5\,10^5$	$1\,\%$
0.03	100000	$4.48\,10^6$	$4\,\%$

4 Modeling C

4.1 Characteristics of modeling C

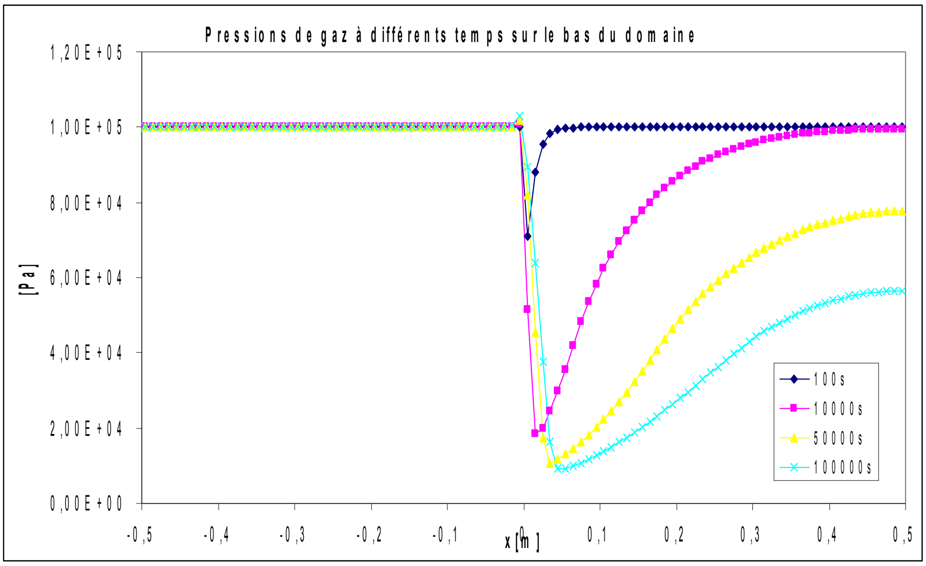
Modeling D_PLAN_HH2SUDA. This modeling corresponds with the diagram Volume Finished Decentred Edge. Coupling LIQU_AD_GAZ. One uses a grid made up of 100 elements QUAD8.
One is into immiscible and one uses a coefficient of infinite Henry of $10^{20}\ Pa.mol^{-1}.m^{3}$,

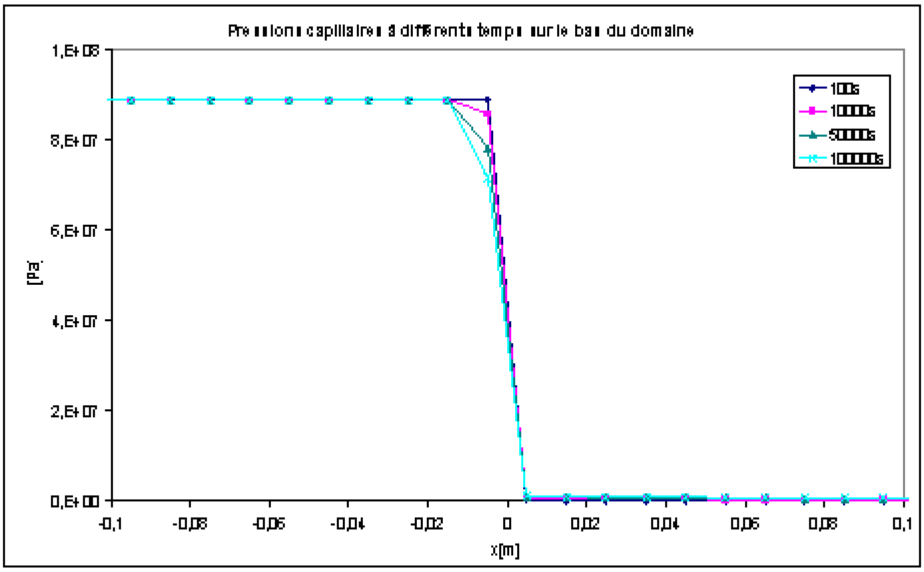
Discretization in time:

- $1000\mathrm{s}$ in 20 pas de time
- $10000\ s$ in 20 pas de time
- 1 month in 20 pas de time
- 2 months in 20 pas de time
- 6 months in 40 pas de time
- 1 year in 50 pas de time
- 10 years in 50 pas de time
- 50 years in 50 pas de time
- 100 years in 50 pas de time
- 500 years in 50 pas de time
- 1000 years in 50 pas de time
- 5000 years in 50 pas de time
- 10,000 years in 50 pas de time
- 100,000 years in 50 pas de time
- 1,000,000 years in 50 pas de time

4.2 Results

The figures below present the profiles of gas pressures and capillary pressures along bi--materials at various times:





The results are those expected. It is noticed that compared to the diagrams finite elements, the gas peak to the interface is almost unperceivable here. It is until one waited of the diagrams eccentric finished volumes. The results are thus coherent.

4.3 Values tested

This case test does not have a value of reference, one thus makes of them a case of nonregression. One carries out tests on two values:

Points (x, y)	**Time (** s **)**	$PRE1$ **Aster**	$PRE2$ **Aster**	**Authorized relative error**
$(-0{,}005{,}0)$ $N105$	100	$8.89\,10^{7}$	19	1%
	100000	$7.175\,10^{7}$	2952	1%
$(0{,}035{,}0{,}005)$ $NQ54$	100	10160	-1745	1%
	100000	$8.532\,10^{5}$	-83702	1%

5 Modeling D

5.1 Characteristics of modeling D

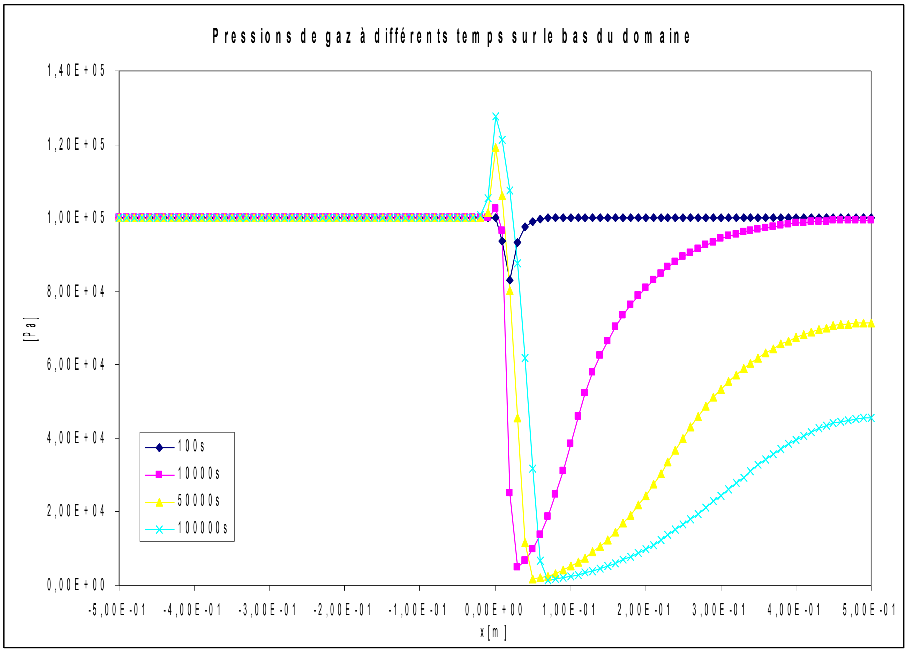
Modeling D_PLAN_HH2S, this modeling corresponds with modeling Finite elements. Coupling LIQU_AD_GAZ. One uses a grid made up of 100 elements QUAD8
One is into immiscible and one uses a coefficient of infinite Henry of $10^{20}\ Pa.mol^{-1}.m^3$,

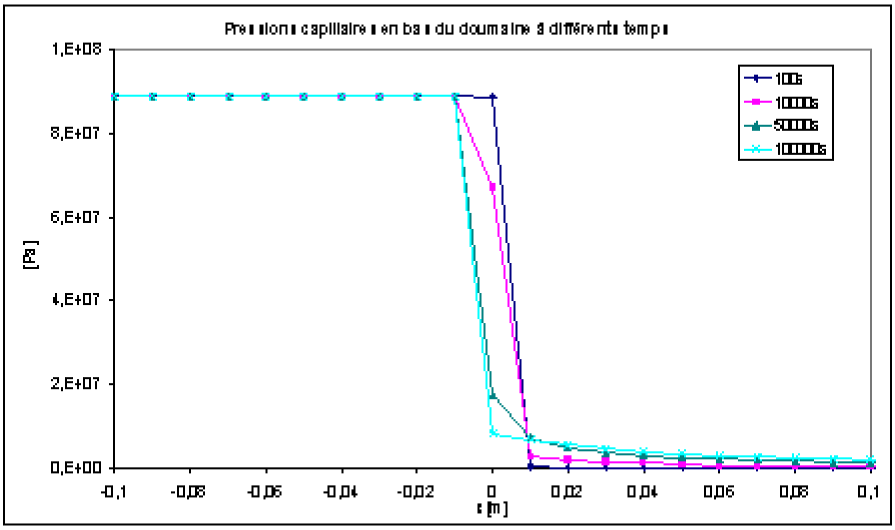
Discretization in time:

- $1000s$ in 20 pas de time
- $10000\,s$ in 20 pas de time
- 1 month in 20 pas de time
- 2 months in 20 pas de time
- 6 months in 40 pas de time
- 1 year in 50 pas de time
- 10 years in 50 pas de time
- 50 years in 50 pas de time
- 100 years in 50 pas de time
- 500 years in 50 pas de time
- 1000 years in 50 pas de time
- 5000 years in 50 pas de time
- 10,000 years in 50 pas de time
- 100,000 years in 50 pas de time
- 1,000,000 years in 50 pas de time

5.2 Results

The figures below present the profiles of gas pressures and capillary pressures along bi--materials at various times:





As for modeling A in finite elements, the peak of gas pressure to the interface is very important here. It is seen well that the finite elements are adapted to this kind of problem than the finite elements.

5.3 Values tested

This case test does not have a value of reference, one thus makes of them a case of nonregression. One carries out tests on two values:

Points (x, y)	**Time (** s **)**	$PRE1$ **Aster**	$PRE2$ **Aster**	**Authorized relative error**
$N111$	100	37569	-6536	1%
	100000	$4.486\,10^{6}$	-12413	1%

6 Summary of the results

This case test meets its main objective well: to test the functionality HYDR_VGM. Moreover it makes it possible to have a classical problem of modeling $« BO - BG »$ with stiff treatment of face. We do not have reference solutions with which to compare to us, however the got results take the classical form of this kind of resolution. We thus make of them a case of nonregression.
2 digital diagrams are tested here: finite elements and eccentric finished volumes edges. If the total pace of the results is the same one for the 2 diagrams, it is seen clearly that finished volumes very strongly decrease the gas peak observed with the interface between materials. If this gas peak has a physical reality, its width is amplified considerably by the diagrams finite elements.

One recommends for this kind of problem the diagrams eccentric finished volumes edges (less expensive than eccentric the meshs).