WTNP120 - Appearance/disappearance of phase in a diphasic flow: Gas injection in a bar saturated with pure water

Summary:

This test represents the simulation of the gas injection in a saturated geological medium.

It is a question of modelling and of simulating the appearance of gas and the evolution of a diphasic water/hydrogen flow in a porous environment initially saturated with pure water. One considers a situation “quasi” - 1D where the effects of gravity are neglected. The case test is presented in a configuration 2D but it can be treated in an equivalent way like a problem 1D.

It is about a miscible purely hydraulic calculation. The geometry represented corresponds to a bar. The terms of transfer are described by a model of Mualem Van-Genuchten. With the problem is dealt by the various diagrams available for the modeling of the diphasic flows: classical finite elements, them Volumes Finis Décentrés Arête, Volumes Finis Décentrés Maille and Volumes Finis Centrés Maille.

1 Problem of reference

1.1 Geometry

The field is a bar of size $[0\text{m}, 200\, m] \times [0\text{m}, 1\text{m}]$:

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.

Liquid water	Density $(kg\,.\,m^{-3})$	1000
	Molar mass $(kg\,.\,mol^{-1})$	10^{-2}
	Viscosity $(kg\,.\,m^{-1}.\,s^{-1})$	10^{-3}
Gas	Density $(kg\,.\,m^{-3})$	$8\,10^{-2}$
	Molar mass $(kg\,.\,mol^{-1})$	$2\,10^{-3}$
	Viscosity $(kg\,.\,m^{-1}.\,s^{-1})$	$9\,10^{-5}$
Dissolved gas	Coefficient of Henry $(Pa\,.\,mol^{-1}.\,m^{3})$	130719
Vapor	Density $(kg\,.\,m^{-3})$	10^{-4}
Homogenized parameters	Permeability K (m^{2})	$5\,10^{-20}$
	Porosity	0.15
	Fick gas $(m^{2}.\,s^{-1})$	0
	Liquid Fick $(m^{2}.\,s^{-1})$	$0{,}45\,10^{-9}$
Parameters of Van-Genuchten	N	$1{,}49$
	$P_r \;\; (MPa)$	2
	S_{rl}	$0{,}4$
	S_{gr}	0
	$Smax$	$0{,}999$
Initial state	Capillary pressure (Pa)	$P_c^0 =\text{-}\, 10^{\text{-}6}$
	Gas pressure (Pa)	$Pgz = 0$

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:

$$S_{le}=\frac{S_l-S_{lr}}{1-S_{lr}} \text{ and } m=1-\frac{1}{n}$$

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

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.

$$k_r^g=\sqrt{(1-S_{le})}(1-S_{le}^{\frac{1}{m}})^{2m} \quad k_r^l=\sqrt{S_{le}}(1-(1-S_{le}^{\frac{1}{m}})^m)^2$$

The permeability to gas is formulated in a similar way:

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

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

The limiting conditions are the following ones:

- conditions of Neumann on the top and the bottom of the field:

$$(F_l^w+F_g^w)\cdot n=0$$
$$(F_l^c+F_g^c)\cdot n=0$$

- conditions of Neumann on the left part of the field:

If $0<t<TSIM$ then $(F_l^w+F_g^w)\cdot n=0$

If $0<t<TINJ$ then $(F_l^c+F_g^c)\cdot n=Q$

If $TINJ<t<TSIM$ then $(F_l^c+F_g^c)\cdot n=0$

- conditions of Dirichlet on the right part of the field:

$$P_l(x=200, y, t)=10^{-6}\,Pa$$
$$P_g(x=200, y, t)=0\,Pa$$

The initial conditions are the following ones:

$$P_l(x, y, t=0)=10^{-6}\,Pa$$
$$P_g(x, y, t=0)=0\,Pa$$

The hydrogen flow imposed on the left part, Q , is worth:

$$Q=1{,}76.10^{-13}\,kg/m^2 s$$

The time of injection, $TINJ$ is of $5.10^5\,ans$ and the time of simulation is of $10^6\,ans$,

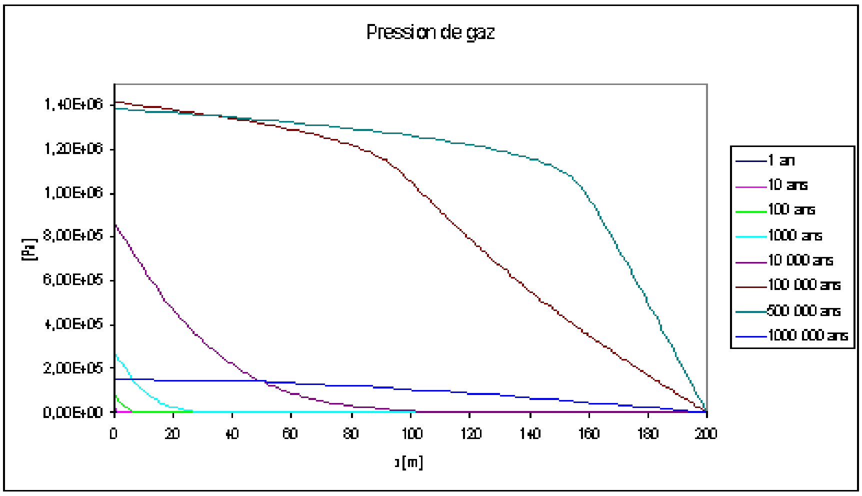
2 Modeling A

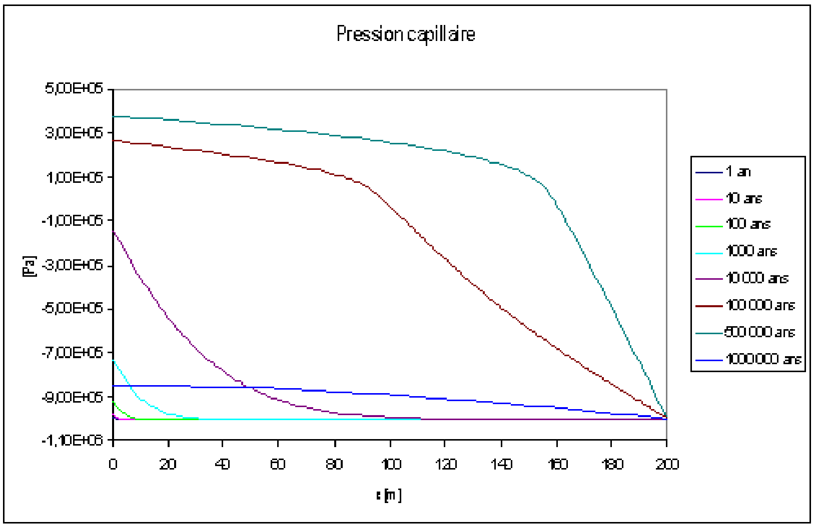
2.1 Characteristics of modeling A

Modeling D_PLAN_HH2SUDA, this modeling corresponds to modeling Volume Finis Décentrés Arête (VFDA). Coupling LIQU_AD_GAZ. One uses a grid made up of 200 elements QUAD8.

2.2 Results

One traces the profiles of pressure of gas and capillary pressures at various times:





It is noted that the gas pressure increases up to 100,000 years then decrease. It is also noted that the gas is diffused in the field in the course of time.

It is noted that one starts with désaturer as from 100,000 years (when the capillary pressure becomes positive). That means that the gas is initially transported only by dissolution/diffusion.
The results are those until we wait.

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 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***
$(0,5 ; 0)$	1 year	-9,98E+005
	1000 years	-7,34E+005
$(0,5 ; 0,5)$	1 year	-9,97E+005
	1000 years	-7,34E+005
$(99,5 ; 0)$	1 year	-9,99E+005
	1000 years	-1,01E+006
$(99,5 ; 0,5)$	1 year	-9,99E+005
	1000 years	-1,00E+006
$(190,5 ; 0)$	1 year	-9,99E+005
	1000 years	-1,00E+006
$(190,5 ; 0,5)$	1 year	-9,99E+005
	1000 years	-1,00E+006

3 Modeling B

3.1 Characteristics of modeling B

Modeling D_PLAN_HH2S. Cette modeling corresponds to modeling classical Finite elements. Coupling LIQU_AD_GAZ. One uses a grid made up of 200 elements QUAD8.

3.2 Results

The results are identical to those obtained with modeling volumes finished eccentric on the edge (Modeling A).

3.3 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 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***
0	1 year	-9,95E+005
	1000 years	-7,22E+005
$(100,0)$	1 year	-9,99E+005
	1000 years	-1,00E+006
$(190,0)$	1 year	-9,99E+005
	1000 years	-1,00E+006

4 Modeling C

4.1 Characteristics of modeling C

Modeling 3D_HH2SUDA. This modeling corresponds to modeling Finished Volumes Decentred Edge (VFDA). Coupling LIQU_AD_GAZ. One uses a grid made up of 502 elements HEXA27.

4.2 Results

The results are very close to those obtained with modeling volumes finished eccentric on the edge (Modeling A).

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 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***	**PRE2** ***Aster***
$(-49,5 ; 0,5 ; 0)$ *NH4*	1 year	-9,96E+005	1,19E+003
	1000 years	-7,46E+005	2,55E+005
$(-1,5 ; 0 ; -0,5)$ *NH195*	1 year	-9,99E+005	4,96E-011
	1000 years	-1,00E+006	9,40E-006
$(-49,5 ; 0 ; 0,5)$ *NH1*	1 year	-9,99E+005	1,19E+003
	1000 years	-7,46E+005	2,55E+005

5 Modeling D

5.1 Characteristics of modeling D

Modeling 3D_HH2S. This modeling corresponds to modeling Finite elements. Coupling LIQU_AD_GAZ. One uses a grid made up of 100 elements HEXA20.

5.2 Results

The results are identical to those obtained with modeling volumes finished eccentric on the edge (Modeling A).

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 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***	**PRE2** ***Aster***
$(-49\ ;-0,5\ ;0,5)$ *N6*	1 year	-9,99E+005	2,168E+003
	1000 years	-7,45E+005	2,55E+005
$(-47\ ;-0,5\ ;0,5)$ *N16*	1 year	-1,00E+006	2,322E-001
	1000 years	-7,91E+006	2,10E+005
$(-48\ ;-0,5\ ;-0,5)$ *N716*	1 year	-1,00E+006	7.86
	1000 years	-7,69E+005	2,32E+005

6 Modeling E

6.1 Characteristics of modeling E

Modeling 3D_HH2MS. The purpose of this modeling corresponds to modeling Finite elements and is just to test modeling 3D_HHMS with imposed flow. Displacements are blocked on the edges of the field. Coupling LIQU_AD_GAZ. One uses a grid made up of 100 elements HEXA20.

6.2 Results

The results are identical to those obtained with modeling volumes finished eccentric on the edge (Modeling A).

6.3 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 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***	**PRE2** ***Aster***
$(-49\ ;-0{,}5\ ;0{,}5)$ $N6$	1 year	-9,99E+005	2,168E+003
	1000 years	-7,45E+005	2,55E+005
$(-47\ ;-0{,}5\ ;0{,}5)$ $N16$	1 year	-1,00E+006	2,322E-001
	1000 years	-7,91E+006	2,10E+005
$(-48\ ;-0{,}5\ ;-0{,}5)$ $N716$	1 year	-1,00E+006	7.86
	1000 years	-7,69E+005	2,32E+005

7 Modeling F

7.1 Characteristics of modeling F

Modeling 3D_HH2MD. The purpose of this modeling corresponds to modeling Finite elements and is just to test modeling 3D_HHMD with imposed flow. Displacements are blocked on the edges of the field. Coupling LIQU_AD_GAZ. One uses a grid made up of 100 elements HEXA20.

7.2 Results

The results are identical to those obtained with modeling volumes finished eccentric on the edge (Modeling A).

7.3 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 6 values:

Points (x, y)	**Time (** s **)**	**PRE1** ***Aster***	**PRE2** ***Aster***
$(-49\ ;-0,5\ ;0,5)$ *N6*	1 year	-9,99E+005	2,168E+003
	1000 years	-7,45E+005	2,55E+005
$(-47\ ;-0,5\ ;0,5)$ *N16*	1 year	-1,00E+006	2,322E-001
	1000 years	-7,91E+006	2,10E+005
$(-48\ ;-0,5\ ;-0,5)$ *N716*	1 year	-1,00E+006	7.86
	1000 years	-7,69E+005	2,32E+005

8 Summary of the results

This test makes it possible to reproduce a classical case of the literature and modeling of storage: gas injection in a saturated medium. We do not have precise reference solutions with which to compare to us, however the values and the pace of the results are in conformity with those of the literature. We thus make of them a case test of nonregression.

This case test makes it possible to test the various diagrams available for the modeling of the diphasic flows in 2D and 3D:

- Classical finite elements
- Finished Volumes Decentred Edge (modeling * _HH2SUDA)

These diagrams give all of the very close results. In terms of performance and reliability.