WTNP124 – Case test of Liakopoulos: Drainage of a water column by the only force of gravity

Summarized:
This case test is the simulation of the experiment of Liakopoulos of 1965 which represents the drainage of a sand column saturated with water. The latter goes then désaturer by the only force of gravity. To represent that, one considers a column $1\,m$ height subjected to the top with an atmospheric gas pressure.

It is about a miscible purely hydraulic computation. The geometry represented corresponds to a vertical 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 modelization of diphasic flows: the conventional finite elements, Eccentric Finished Volumes Edge , Eccentric Finished Volumes and the Nets Centered Finished Volumes.

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

1 Problem of reference

This benchmark represents the desaturation of a column initially saturated with water by gravitating effect (experiment of Liakopoulos). Here we consider that the air can dissolve in water (version proposed by VAUNAT in 1997).

1.1 Geometry

the field is a bar of size $[0\mathrm{m}\,;0{,}1\,m]\times[0\mathrm{m}\,;1\mathrm{m}]$.

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.

Liquid water	Density $(kg.m^{-3})$	1000
	Molar mass $(kg.mol^{-1})$	10^{-2}
	Viscosity $(kg.m^{-1}.s^{-1})$	10^{-3}
	compressibility	$0{,}5\,10^{-9}$
Gas	Density $(kg.m^{-3})$	$8\,10^{-2}$
	Molar mass $(kg.mol^{-1})$	$28{,}96\,10^{-3}$
	Viscosity $(kg.m^{-1}.s^{-1})$	$1{,}8\,10^{-5}$
dissolved Gas	Coefficient of Henry $(Pa.mol^{-1}.m^{3})$	$2\,10^{-6}$
Vapor	Density $(kg.m^{-3})$	$18\,10^{-3}$
homogenized Parameters	Permeability k (m^{2})	10^{-12}
	Porosity	$0{,}2975$
	Fick liquid $(m^{2}.s^{-1})$	0
	gas Fick $(m^{2}.s^{-1})$	0
Parameters of Van-Genuchten	N	2
	P_r MPa	10^{4}
	S_{rl}	0
	S_{gr}	0
	$Smax$	$0{,}999$
State initial	liquid Pressure	$P_l^0=\rho\,g\,Y+1\,atm-\rho\,g$
	gas Pressure	$P_g^0=1\,atm$

Table 1.2-1 : Properties of the materials

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

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

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

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

the permeability relating to water is expressed by integrating the model prediction proposed by Mualem (1976) in the model of capillarity of Van Genuchten: $k_r^l=\sqrt{S_{le}}\left(1-\left(1-S_{le}^{\frac{1}{m}}\right)^m\right)^2$

The permeability with gas is formulated in a similar way: $k_r^g=\sqrt{(1-S_{le})}\left(1-S_{le}^{\frac{1}{m}}\right)^{2m}$

It is pointed out 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 flat rims and left of the field:

$$(\boldsymbol{F}_l^w+\boldsymbol{F}_g^w).\boldsymbol{n}=0$$
$$(\boldsymbol{F}_l^c+\boldsymbol{F}_g^c).\boldsymbol{n}=0$$

- conditions of Dirichlet on the high part of the field (surface to open air):

$$P_g(x,y=1,t)=10^5 \quad Pa$$

- conditions of Dirichlet on the low part of the field (saturated medium; water runs out):

$$P_g(x,y=0,t)=10^5 \quad Pa$$
$$P_l(x,y=0,t)=10^5 \quad Pa$$

The initial state corresponds in a state saturated with water with the hydrostatic equilibrium. The initial conditions are the following ones:

$$P_l(x,y,t=0)=\rho g(Y-1)+10^5$$
$$P_g(x,y,t)=0=10^5 \quad Pa$$

1.4 Time of simulation

The computation is carried out over one year $(3.1536.10^7 s)$.

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

2 Modelization A

2.1 Characteristic of the modelization A

Modelization `D_PLAN_HH2SUDM`. This modelization corresponds to the modelization Volume Finished Eccentric Nets. Coupling `LIQU_AD_GAZ`. One uses a mesh made up of 50 elements `QUAD8`.

2.2 Results

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

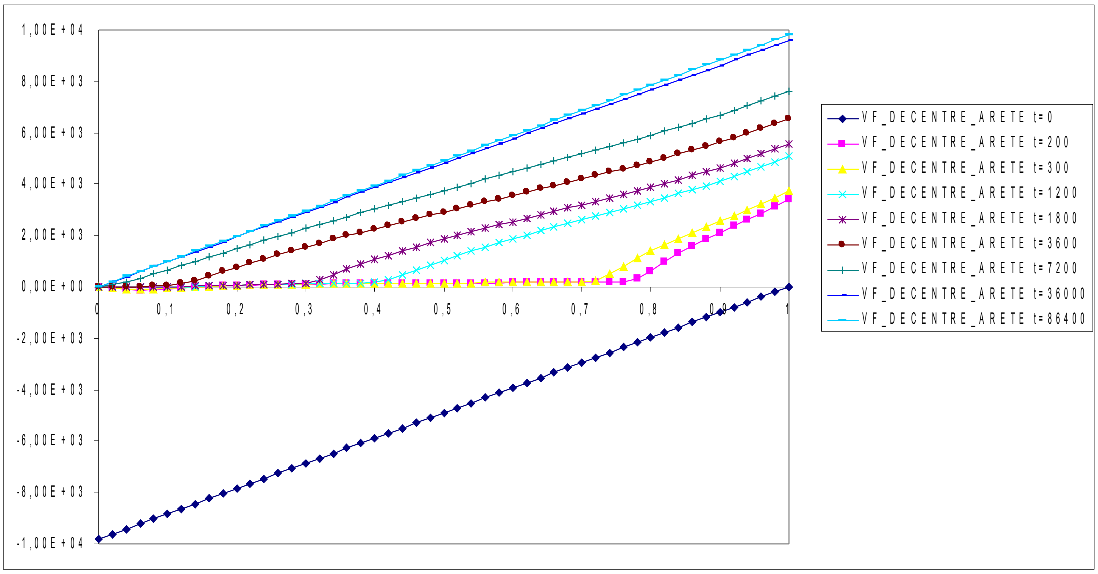

Illustration 1: Capillary pressure along the column

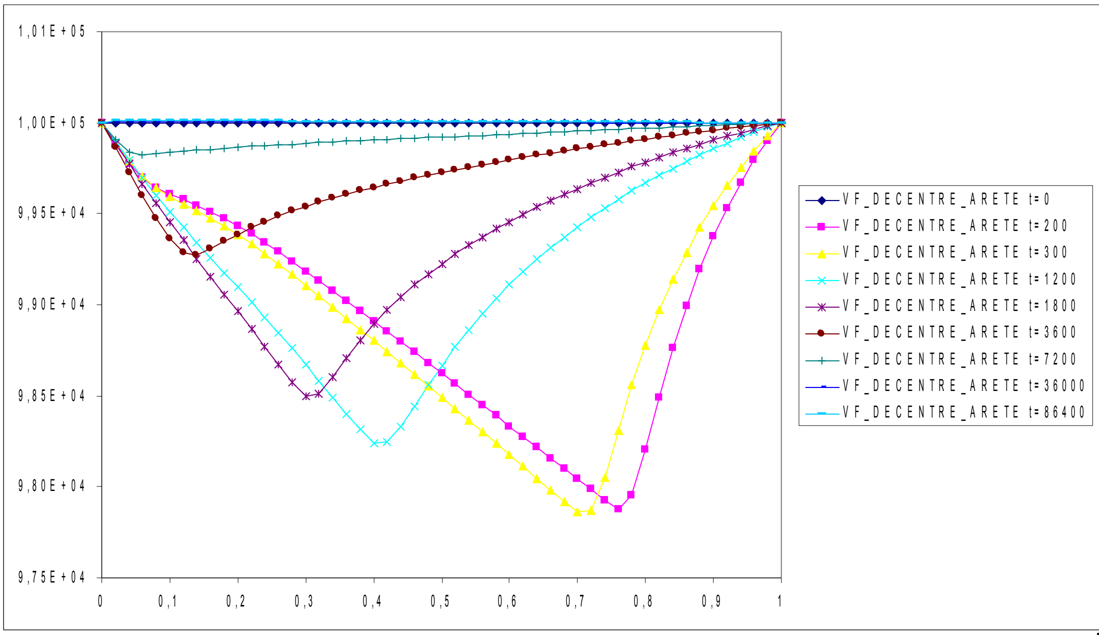

Illustration 2: Gas pressure along the column

Warning : T... part and is
provided as ...

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

One observes well a progressive desaturation of the medium (when the capillary pressure becomes positive). The desaturation on all the column and the permanent state are obtained at the end of one day ($86400\,s$). The profiles of gas pressure have a pace in “point” whose change of incline corresponds to the front of saturation. In saturated zone, the gas pressure is controlled by the quantity of dissolved air; above front of saturation, the flux of air is primarily related to the movement of dry air. This shape of curve is typical of this kind of problem and corresponds well so that one finds in the literature.

2.3 Values tested

This benchmark does not have a value of reference precise, one thus makes a case of non regression of them.

One carries out tests on 6 values:

Points (x, y)	**Time** (s)	**PRE1** ***Aster***	**PRE2** ***Aster***
$(0{,}05\,;1)$ $N103$	200s	3377.	1.00E+05
	86400 S	9811.	1.00E+05
$(0{,}05\,;0{,}5)$ $N229$	86400 S	4911.	1.00E+05

Table 2.3-1 : Values tested

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

3 Modelization B

3.1 Characteristic of the modelization B

Modelization D_PLAN_HH2SUDA. This modelization corresponds to the modelization Volume Finished Eccentric Edges. Coupling LIQU_AD_GAZ. One uses a mesh made up of 50 elements QUAD8.

3.2 Results

the results are very close to those obtained with the modelization volumes finished eccentric on the mesh.

3.3 Values tested

This case test does not have a value of reference, one thus makes a case of non regression of them.

One carries out tests on 6 values:

Points (x, y)	**Time** (s)	**PRE1** ***Aster***	**PRE2** ***Aster***
$(0,05\,;1)$ *N103*	200s	60.15.	98259.
	86400 S	9810.	1.00E+05
$(0,05\,;0,5)$ *N229*	86400 S	4912.	1.00E+05

Table 3.3-1 : Values tested

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

4 Modelization C

4.1 Characteristic of the modelization C

Modelization D_PLAN_HH2SUC. This modelization corresponds to the modelization Volume Finished Centered. Coupling LIQU_AD_GAZ. One uses a mesh made up of 50 elements QUAD8.

4.2 Results

the results are very close to those obtained with the modelization volumes finished eccentric on the mesh.

4.3 Values tested

This case test does not have a value of reference, one thus makes a case of non regression of them.

One carries out tests on 6 values:

Points (x, y)	**Time** (s)	**PRE1 *Aster***	**PRE2 *Aster***
$(0{,}05; 1)$ *N103*	200s	3384.	1.00E+05.
	86400 S	9811.	1.00E+05
$(0{,}05; 0{,}5)$ *N229*	86400 S	4911.	1.00E+05

Table 4.3-1 : Values tested

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

5 Modelization D

5.1 Characteristic of the modelization D

Modelization `D_PLAN_HH2S`. This modelization corresponds to the modelization Finite elements. Coupling `LIQU_AD_GAZ`. One uses a mesh made up of 50 elements `QUAD8`.

5.2 Results

the results are very close to those obtained with the modelization volumes finished eccentric on the mesh.

5.3 Values tested

This case test does not have a value of reference, one thus makes a case of non regression of them.

Points (x,y)	**Time** (s)	**PRE1** ***Aster***	**PRE2** ***Aster***
$(0;0{,}049)$ *N51*	200s	-124.6	99689.
	1800s	-9.475	99659.
	86400 S	600.1	1.00E+05
$(0;1)$ *N2*	200s	3445.	1.00E+05
	1800s	5604.	1.00E+05
	86400 S	9811.	1.00E+05

Table 5.3-1 : Values tested

6 Summary of the results

This case test proposes a modelization of the very classical experiment of Liakopoulos. Simulations reproduce perfectly the expected results, even if we do not have numerical reference of results. This test enables us to validate the good taking into account of gravity by the various numerical diagrams. With this problem is indeed dealt with the 4 numerical diagrams available for the modelization of diphasic flows:

- the 3 diagrams finished volumes: centered, decentred edge, decentred mesh
- the conventional finite elements

the got results are the same ones. In term of performance and reliability, one will strongly privilege the diagrams Eccentric Finished Volumes Edge (`*_HH2SUDA`).

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)