Mass-Conservation Tests

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Contents

1 PorousFlowComponentMass postprocessor

1.1 Single-phase, single-component

The total fluid mass of species sp within a volume V is

$$\int_V \phi \sum_{\mathrm{ph}} \rho_{\mathrm{ph}} S_{\mathrm{ph}} \chi_{\mathrm{ph}}^{\mathrm{sp}} . \tag{1.1}$$

It must be checked that MOOSE calculates this correctly in order that mass-balances be correct, and also because this quantity is used in a number of other tests

A 1D model with $-1 \leq x \leq 1$, and with three elements of size 1 is created with the following properties:

Constant fluid bulk modulus	1 Pa
Fluid density at zero pressure	1 kg.m^{-3}
Van Genuchten m	0.5
Van Genuchten α	1 Pa^{-1}
Porosity	0.1

The porepressure is set at $P = x$.

Recall that in PorousFlow, mass is lumped to the nodes. Therefore, the integral above is evaluated at the nodes, and a sum of the results is outputted as the PorousFlowComponentMass postprocessor. Using the properties given above, this yields:

x	p	Density	Saturation	Nodal mass
-1	-1	0.367879441	0.707106781	0.008671002
-0.333333333	-0.333333333	0.716531311	0.948683298	0.02265871
-0.333333333	-0.333333333	0.716531311	0.948683298	0.02265871
0.333333333	0.333333333	1.395612425	1	0.046520414
0.333333333	0.333333333	1.395612425	1	0.046520414
1	1	2.718281828	1	0.090609394
			Total	0.237638643

MOOSE also gives the total mass as 0.237638643 kg. This test is part of the automatic test suite that is run every time the code is updated.

1.2 Single-phase, two-components

The same test as Section 1.1 is run but with two components. The mass fraction is fixed at

$$\chi^{\mathrm{sp}=0}_{\mathrm{ph}=0} = x^2 \ . \tag{1.2}$$

x	p	Density	Saturation	$\chi^{\mathrm{sp}=0}_{\mathrm{ph}=0}$	Nodal mass$_{\mathrm{sp}=0}$	Nodal mass$_{\mathrm{sp}=1}$
-1	-1	0.367879441	0.707106781	1	0.008671	0
-0.333333333	-0.333333333	0.716531311	0.948683298	0.111111	0.00251763	0.02014108
-0.333333333	-0.333333333	0.716531311	0.948683298	0.111111	0.00251763	0.02014108
0.333333333	0.333333333	1.395612425	1	0.111111	0.00516893	0.04135148
0.333333333	0.333333333	1.395612425	1	0.111111	0.00516893	0.04135148
1	1	2.718281828	1	1	0.09060939	0
				Total	0.11465353	0.12298511

MOOSE produces the expected answer.

1.3 Two-phase, two-components

This test computes the mass for two components in two phases, with both components present in both phases. The mass fractions are fixed at

$$\chi^{\mathrm{sp}=0}_{\mathrm{ph}=0} = 0.3\ , \chi^{\mathrm{sp}=0}_{\mathrm{ph}=1} = 0.55. \tag{1.3}$$

Pressure is fixed at 1 Pa for each phase, and density is given by a constant bulk modulus fluid with denisty at zero pressure given by 1 Pa and 0.1 Pa for phase 0 and phase 1, respectively, giving densities of 2.7128 kg m^{-3} for phase 0, and 0.27128 kg m^{-3} for phase 1. Saturation of phase 0 varies linearly with x throughout the 1D model with three elements from $0 \leq x \leq 1$

For component species 0, the mass at each node is calculated as

x	$S_{\mathrm{ph}=0}$	$\chi^{\mathrm{sp}=0}_{\mathrm{ph}=0}$	$\chi^{\mathrm{sp}=0}_{\mathrm{ph}=1}$	Nodal mass$^{\mathrm{sp}=0}_{\mathrm{ph}=0}$	Nodal mass$^{\mathrm{sp}=0}_{\mathrm{ph}=1}$	Total nodal mass$^{\mathrm{sp}=0}$
0	0	0.3	0.55	0	0.00249176	0.00249176
0.33333	0.33333	0.3	0.55	0.00453047	0.00166117	0.00619164
0.33333	0.33333	0.3	0.55	0.00453047	0.00166117	0.00619164
0.66667	0.66667	0.3	0.55	0.00906094	0.000830586	0.009891526
0.66667	0.66667	0.3	0.55	0.00906094	0.000830586	0.009891526
1	1	0.3	0.55	0.0135914	0	0.0135914
			Total	0.0407742	0.0074753	0.0482495

For component species 1, the mass at each node is calculated as

x	$S_{\mathrm{ph}=0}$	$\chi^{\mathrm{sp}=0}_{\mathrm{ph}=0}$	$\chi^{\mathrm{sp}=0}_{\mathrm{ph}=1}$	Nodal mass$^{\mathrm{sp}=0}_{\mathrm{ph}=0}$	Nodal mass$^{\mathrm{sp}=0}_{\mathrm{ph}=1}$	Total nodal mass$^{\mathrm{sp}=0}$
0	0	0.7	0.45	0	0.00203871	0.00203871
0.33333	0.33333	0.7	0.45	0.01057110	0.001359141	0.01193024
0.33333	0.33333	0.7	0.45	0.01057110	0.001359141	0.01193024
0.66667	0.66667	0.7	0.45	0.02114219	0.000679570	0.02182176
0.66667	0.66667	0.7	0.45	0.02114219	0.000679570	0.02182176
1	1	0.7	0.45	0.03171329	0	0.03171329
			Total	0.0951399	0.06116113	0.1012560

MOOSE produces the expected answer.