Pressure Diffusion Wellbore Storage @model

Mathematical model of dynamic wellbore storage effects is based on the idea that if surface rate changes δq_s at certain moment then it will take some time before the pressure disturbance reach the bottomhole and induce sandface flow variance δq_t :

(1) $$< \delta q_s \, B >= \delta q_t + C_S \, \frac{dp_{wf}}{dt}$$

where

q_s	surface flow rate
$< \delta q_s \, B >$	allocation of surface rate to the sandface conditions $< \delta q_s \, B >= B_w \, \delta q_W + (B_o - R_s \, B_g) \, \delta q_O + (B_g - R_v \, B_o) \, \delta q_G$
q_t	total water, oil, gas sandface flowrate
p_{wf}	bottom-hole pressure
C_S	constant value called wellbore storage (WBS)

In stationary conditions the surface fluid volumes q_s and sandface volumes q_t are related through formation volume factor B for Simple PVT case:

(2) $$< \delta q_s \, B >= \delta q_t$$

or

(3) $$< \delta q_s \, B >= B_w \, \delta q_W + (B_o - R_s \, B_g) \, \delta q_O + (B_g - R_v \, B_o) \, \delta q_G = \delta q_t$$

for multi-phase fluid production (Non-linear multi-phase pressure diffusion @model:3).

For constant wellbore storage the early time pressure response (ETR) build up is charcaterized by linear dependence on time:

(4) $$p_{wf}(t) = p_{wf}(0) - \frac{q_s}{C_S} \, t$$

The formula (1) is empirical and has very generic view simply stating that in the moment of well opening there will be a difference between surface and subsurface flow which is proportional to time derivative of pressure and hence will vanish when pressure stabilises.

The actual form of the function $C_S(p_{wf})$ depends on the particular physics of fluid flow inertial effect and few of them are explained below.

Wellbore storage from fluid compressibility

The simplest case is when borehole is filled with fluid at all times which makes calculation of wellbore storage easy:

(5) $$C_S = c\, V_{wb}$$

where c – fluid compressibility, V_{wb} – wellbore volume available for flow.

This normally happens for water injectors and gas wells (producers or injectors) at high formation pressure.

In case of water injector the fluid compressibility is constant $c(p) = \mathrm{const}$ at all pressures and if well has no integrity issues the wellbore volume V_{wb} will remain constant in time leading to a constant wellbore storage $C_S = \mathrm{const}$.

In case the whole wellbore volume is filled with fluid at the moment of opening or closing the well at surface the wellbore fluid compressibility is going to be:

(6) $$c = \frac{1}{V_{wb}} \frac{\delta V_{wb}}{\delta p}$$

In the very first moments the surface fluid will only compress (for injectors) or decompress (for producers) the wellbore fluid column without communication with subsurface formation thus leading to the following correlation:

(7) $$\frac{dp}{dt} = \frac{1}{c\, V_{wb}} \frac{dV}{dt} = \frac{1}{c\, V_{wb}} \frac{dV}{dt}$$

or

(8) $$\delta q_s = \delta q_t - c\, V_{wb} \frac{dp_{wf}}{dt}$$

providing that $q_s = 0$ until fluid column has reached a surface the surface .

Comparing (8) to (1) one arrives to (5)

Wellbore storage from varying fluid level

In case of oil producers the dynamic fluid level is always below surface and shutting the well down will cause after flow from formation and fluid level rise at constant pace q with the following wellbore storage:

(9) $$C_S = \frac{A}{\rho\, g}$$

where ρ – fluid density, A – wellbore cross-sectional area available for flow, g – standard gravity.

The true vertical pressure difference between two points of a rising fluid column is:

(10) $$\Delta p = \rho g \Delta h = \frac{\rho g}{A} \Delta V$$

The pressure build up then:

(11) $$\frac{dp}{dt} = \frac{\rho g}{A} \frac{dV}{dt} = \frac{\rho g}{A} q$$

or

(12) $$\delta q_s = \delta q_t - \frac{A}{\rho g} \frac{dp_{wf}}{dt}$$

providing that $q_s = 0$ until fluid column has reached a surface the surface .

Comparing (12) to (1) one arrives to (9)

Varying wellbore storage

See Also

Petroleum Industry / Upstream / Subsurface E&P Disciplines / Well Testing / Pressure Testing / Wellbore Storage

Physics / Mechanics / Continuum mechanics / Fluid Mechanics / Fluid Dynamics / Pressure Diffusion / Pressure Diffusion @model