Linear Flow Pressure Diffusion @model

Motivation

In many practical cases the reservoir flow created by well or group of wells is getting aligned with a specific linear direction away from wells (see linear fluid flow).

This happens when wells are placed in a channel or a narrow compartment.

It also happens around fracture planes and conductive faults. It also develops temporarily at early times of the transients in horizontal wells.

This type of flow is called linear fluid flow and corresponding PTA type library models provides a reference for linear fluid flow diagnostics.

Inputs & Outputs

Inputs		Outputs	
q_t	total sandface rate	$p(t,x)$	reservoir pressure
p_i	initial formation pressure	$p_{wf}(t)$	well bottomhole pressure
d	reservoir channel width		
σ	transmissibility, $\sigma = \frac{k\,h}{\mu}$		
χ	pressure diffusivity, $\chi = \frac{k}{\mu}\,\frac{1}{\phi\,c_t}$		

k	absolute permeability	c_t	total compressibility, $c_t = c_r + c$
h	effective thickness	c_r	pore compressibility
μ	dynamic fluid viscosity	c	fluid compressibility
ϕ	porosity		

Physical Model

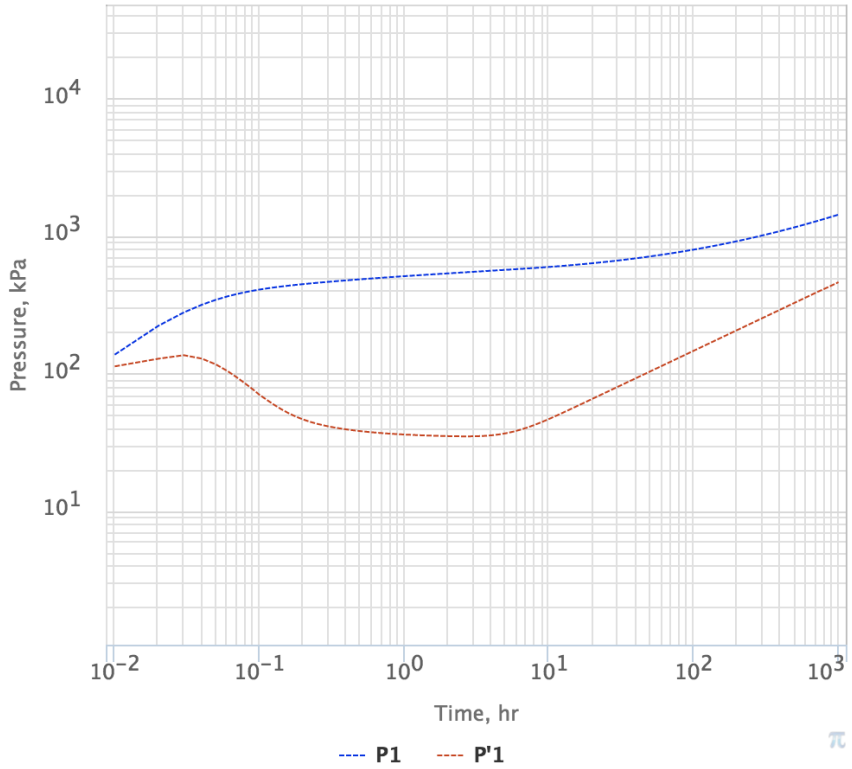
Linear fluid flow	Homogenous reservoir	Infinite boundary	Zero wellbore radius	Slightly compressible fluid flow	Constant rate production
$p(t,\mathbf{r}) \to p(t,x)$ $\mathbf{r} \in \mathbb{R}^2 = \{x,y\}$	$M(x,p) = M = \text{const}$ $\phi(x,p) = \phi = \text{const}$ $h(x) = h = \text{const}$	$0 \le x \to \infty$	$x_w = 0$	$c_t(p) = c_r + c = \text{const}$	$q_t = \text{const}$

Mathematical Model

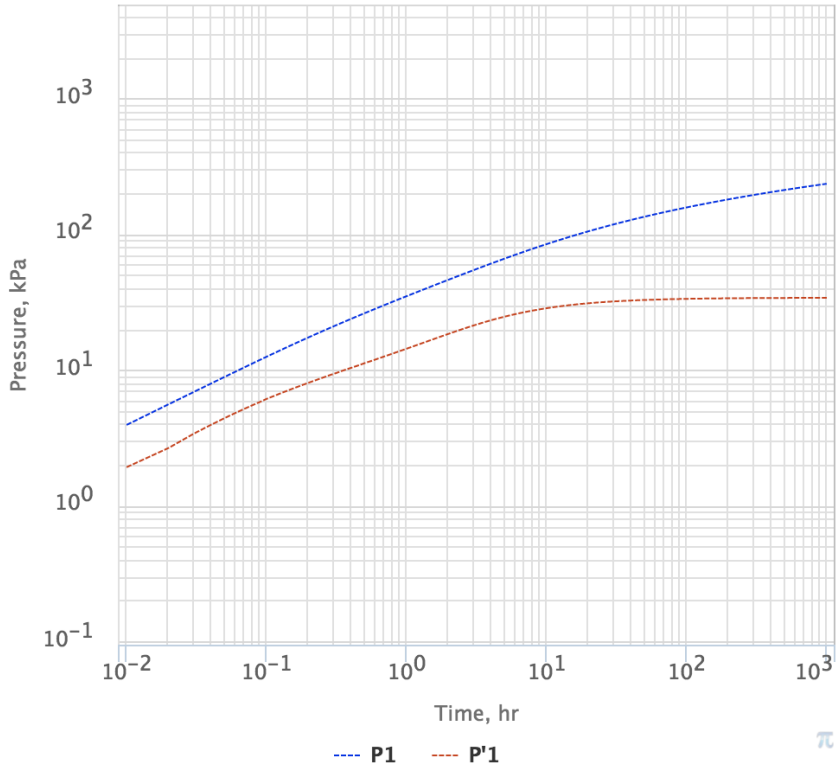
(1) $\frac{\partial p}{\partial t} = \chi \frac{d^2 p}{dx^2}$	(2) $p(t=0,x) = p_i$	(3) $p(t, x \to \infty) = p_i$	(4) $\left.\frac{\partial p(t,x)}{\partial x}\right\|_{x \to 0} = \frac{q_t}{\sigma\, d}$
(5) $p(t,x) = p_i - \frac{q_t}{\sigma\, d}\left[\sqrt{\frac{4\chi t}{\pi}} \exp\left(-\frac{x^2}{4\chi t}\right) - x\left[1 - \operatorname{erf}\left(\frac{x}{\sqrt{4\,\chi\, t}}\right)\right]\right]$		(6) $p_{wf}(t) = p(t, x=0) = p_i - \frac{q_t}{\sigma\, d}\sqrt{\frac{4\chi t}{\pi}}$	

Applications

Pressure Testing – Channel or Narrow reservoir compartment

Pressure Drop	(7) $\delta p = p_i - p_{wf}(t) \sim t^{1/2}$	
Log derivative	(8) $t\frac{d(\delta p)}{dt} \sim t^{1/2}$	
		Fig. 2. PTA Diagnostic plot for linear fluid flow in reservoir channel

Pressure Testing – Infinite conductivity fracture

Pressure Drop	(9) $\delta p = p_i - p_{wf}(t) \sim t^{1/2}$	
Log derivative	(10) $t\frac{d(\delta p)}{dt} \sim t^{1/2}$	
		Fig. 2. PTA Diagnostic plot for linear fluid flow in infinite conductivity fracture

See also

Physics / Fluid Dynamics / Linear fluid flow

[Radial Flow Pressure @model] [1DR pressure diffusion of low-compressibility fluid] [Exponential Integral]

[Petroleum Industry / Upstream / Subsurface E&P Disciplines / Well Testing / Pressure Testing]