Why Coupling?

2019년 9월 20일 금요일 오후 7:18

Change in fluid volume in a reservoir

↓ (injection, production, phase change)

Pore pressure change

↓

Effective stress change

↓

Rock deformation / failure

↓ ↳ Displacement

Porosity change

↳ Permeability change

↓

Solve flow equations in new ϕ and k

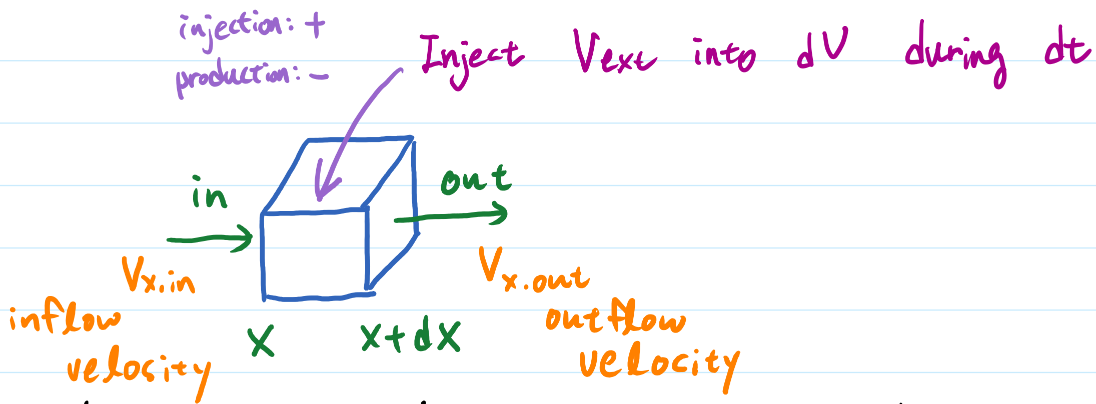
flow simulation

mechanical simulation

Mass Conservation Considering Rock Deformation

mass balance over dV and dt

(dV: small volume; dt: small time interval)



First only x-direction is considered.

Accumulation in dV during dt is calculated in two different ways, and they equal.

Mass Balance : During a very short time, inlet fluid mass = outlet fluid mass in a very small rock volume

mathematically

$$\nabla\cdot(\rho v) + \frac{\partial}{\partial t}(\phi\rho) = \frac{1}{\partial x\partial y\partial z}\frac{\partial(\rho V_{ext})}{\partial t}$$

However, if we consider rock deformation caused by effective stress changes in the rock, then the bulk volume changes.

In the mass balance equation, we assume that the bulk volume (= very small rock volume) is constant, but this is not valid any longer if the rock is deformed.

Thus, we replace ϕ with ϕ^*

$$\phi = \text{true porosity} = \frac{V_p}{V_b} = \frac{\text{current pore volume}}{\text{current bulk volume}}$$

ϕ^* = reservoir porosity = $\frac{V_p}{[illegible]}$ = $\frac{\text{current pore volume}}{[illegible]}$

V_b current bulk volume

$$\phi^* = \text{reservoir porosity} = \frac{V_p}{V_b^0} = \frac{\text{current pore volume}}{\text{initial bulk volume}}$$

↳ This is the ratio of current pore volume to initial bulk volume, so we don't need to worry about the bulk volume change.

$$\nabla \cdot (\rho v) + \frac{\partial}{\partial t}(\phi^* \rho) = \frac{1}{\partial x \partial y \partial z} \frac{\partial(\rho V_{ext})}{\partial t}$$

$$\phi^* = \phi(1 - \varepsilon_v)$$

ε_v: volumetric strain

$$\varepsilon_v = \frac{V_b^0 - V_b}{V_b^0}$$

$$\phi = \frac{V_p}{V_b}, \quad \phi^* = \frac{V_p}{V_b^0}$$

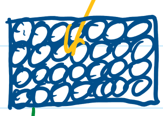
$$\phi^* = \frac{V_p}{V_b^0} = \frac{\phi V_b}{V_b^0} = \frac{\phi(1-\varepsilon_v)V_b^0}{V_b^0} = \phi(1-\varepsilon_v)$$

Replace ϕ with ϕ^* the flow equation.

ϕ^* is updated in the mechanical simulation.

* Intuition

fluid injection → Pore pressure ↑



bulk volume

→ Bulk volume ↑ or constant?

Bulk volume remains constant and Only pore volume up?

Geomechanical Equations for Deformable Porous Media

2019년 7월 15일 월요일 오후 1:35

We need four geomechanical equations
to describe stress and strain in deformable porous media.

1) Force equilibrium equation
2) Strain - Displacement relation
3) Total and effective stress relation
4) Constitutive relation