Introduction
The mechanical response of mud shale under the action of multiple field coupling is always a hot topic in the field of drilling engineering. In this paper, a multi-field coupled model is established, using the solid mechanics module embedded in COMSOL and combined with the General form in PDE module to complete the setting of the model. The grid encryption function is used to encrypt the area around the well, which makes the calculation results more advanced and more in line with the actual situation on site. The results show that the collapse process of rock around the shaft wall is a dynamic evolution process involving space and time, and COMSOL can well simulate the above 4-D process. The simulation results can be used to analyze and simulate the effect of time dependence on wellbore stability during drilling. It can also help drilling engineers design drilling plans (including design and calculation of mud safety density window, mud salinity, etc.).

Coupling model
Navier equations for displacements: A momentum balance equation is employed to derive the Navier type equation for displacements as:
\[
(K + \omega^2\omega V)u + GVu = \alpha\rho p + \eta_2\omega V^2 - \gamma V T = 0
\]
(1)
where \(K\) and \(G\) are bulk and shear moduli, \(u(x,t)\) is the rock displacement and \(T\) is the temperature of the porous medium.

Pressure diffusion equation: Using conservation of mass for a weakly compressible fluid along with the expression for the flux gives a coupled fluid diffusion equation as:
\[
\frac{\partial p}{\partial t} + (\rho + \rho_B) \frac{\partial}{\partial x} \left[ \frac{\partial}{\partial x} \right] - \gamma \frac{\partial^2 p}{\partial x^2} + \frac{p_k - p_m}{\mu} \frac{\partial^2 T}{\partial x^2} = 0
\]
(2)
where \(\gamma\) is the Biot’s Coefficient, \(p\) is pore pressure, \(K\) is permeability, the fluid viscosity is \(\mu\), and \(\eta\) are the components of total strain tensors and solute mass fractions. Also, \(\omega\) is the standard solute reflection coefficient (or membrane efficiency), \(R\) is the universal gas constant. \(\rho\) is the molar mass of the solute, \(\gamma\) is the thermal osmosis coefficient.

Equation for solute diffusion: Conservation of a solute mass in rock yields the following equation for solute transfer:
\[
\frac{\partial}{\partial t} (\rho_0 S) + \nabla \cdot (\rho_0 S \mathbf{u}) = \nabla \cdot (\rho_0 \mathbf{J})
\]
(3)
Where \(D\) is the solute diffusion coefficient and \(\gamma\) is the coefficient of thermal diffusion.

Equation for thermal conduction: Conservation of energy balance in the rock yields the following equation for thermal conduction:
\[
\frac{\partial}{\partial t} C_T T + \nabla \cdot (\rho C_T \mathbf{u}) = \nabla \cdot (\kappa \nabla T)
\]
(4)
The coefficients in the governing equations are:
\[
\chi = \frac{1}{\rho C_T} \frac{\partial C_T}{\partial T}
\]
\[
\beta = \frac{s M_F k}{K T c_T}
\]
\[
\gamma = \frac{\alpha + \beta}{\kappa} + \frac{(\alpha - \beta) M_T}{K T c_T}
\]
boundary conditions
It is assumed that compressive stress is positive and tensile stress is negative. The rock is considered as a homogenous porous medium. The plane strain hypothesis and instantaneous drilling are used to solve the non-linear system of equations. Solving the non-linear system of equations requires knowledge of the initial solute concentration, temperature and pore pressure within the flow domain.

Calculation results

The drilling engineer is very concerned about the stress and chemical physical state around the well. The stress state around the hole can be simulated well by using COMSOL software. This can help engineers solve engineering problems.

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