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Prediction of sanding in subsurface hydrocarbon reservoirs

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Background

We are a start-up company which targets the hydrocarbon reservoir engineering community. We develop software tools for simulation of subsurface flows in deformable porous media. This is being done by modeling the physical problem by a system of partial differential equations. This system is discretized numerically and solved at a number of time steps. As a result of a simulation one has, as primary variable, the mechanical displacements and the fluid pressure resolved at any spatial location and time instance. A number of derived quantities, such as mechanical stresses, fluid velocity, etc are also computed. We are interested to relate such computations to localized processes which occur in particular locations in a subsurface reservoir.

The problem

Of primary interest is the nature of the solution near wellbores. These are the locations in a reservoir model from where fluids are injected/extracted. Locally, many physical changes may occur, which cannot be represented within the general framework of coupled poro-mechanics that is used to generate a solution, globally, that is in the entire reservoir. Global solutions have a characteristic lengthscale of tens of meters, while wellbores have radius of a few centimeters to tens of centimeter. Consequently, the global solution that is computed need to be appropriately downscaled near wellbores to help understand the local physics.

We are interested in the local phenomena of sanding. Near wellbores the fluid velocity can become quit high, effecting high friction on the porous rock. Moreover, due to drilling operations the mechanical stresses can exceed the load bearing capacity of the rock. As a result, the rock can be fractured into sand, which is then carried by the fluid through the wellbore. This process, known as sanding, can severely and negatively impact the production at given well. Sand is abrasive to equipment, can clog flow lines and diminish hydrocarbon recovery. In a worst case scenario, sanding can remove sufficient quantities of rock to produce subsurface cavities which then collapse, destroying the well and associated equipment.

As a rule of thumb, every effort is made to avoid the conditions which lead to sanding. When sanding is unavoidable it is necessary to estimate the magnitude of the problem. What we would like to do, as part of this study group is to generate a simple one-dimensional local model which predicts the volume of sanding based on stresses and fluid velocities near a well. To do this, we take certain values for globally computed fluid pressure and mechanical stresses. We then exploit the radial symmetry of a well to compute localized stresses and pressure at the wellbore surface. These are known in the literature and will be provided. The goal is then to develop link the local stress state and a particular fluid velocity in a model which predicts the rate of sanding. Literature describing general criteria for sanding and associated volume of produced sand will also be provided.

In general, as the local stress exceeds certain level, a certain total amount of rock is fractured into sand. Then, depending on the flow rate this sand is removed at a certain rate. Finally, as sand is removed, the wellbore geometry changes. The main utility of a 1D model is to determine:

1. Sensitivity to global stresses and fluid pressure.
2. Derive an approximation for the change in wellbore radius as a result of sand removal.

Such a toy model will help our company in designing complex 3D local models. In such models, the wellbore trajectory and surface is resolved by a local grid. A good understanding of the radially symmetric response will be invaluable to generating complex 3D models with field-scale quantities coupled two-ways to the local response.