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A Numerical Method of Coupled Reservoir-Geomechanical Problem Using High Resolution for Fluid Flow Domain

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Accurate prediction of petroleum reservoir production in structurally weak geologic areas such as fractured reservoirs or low-permeability reservoirs requires both mechanical deformation and fluid flow modeling. Even production of reservoirs located in stable environments may also need to be predicted by fluid-solid coupled models in case of injection of water or carbon dioxide. The equations governing the interaction of solid and fluid in rocks are equilibrium equation and continuity equation. Generalized finite element method is usually adopted for the fluid-solid coupled models, however it needs rather much effort in programming and is not satisfactory in computational efficiency. The mixed finite element and finite volume scheme is proposed as an alternative method since it involves less computational effort and improves the simulation efficiency. In the mixed FEM-FVM method, the equilibrium equation is discretized in the spatial domain for geomechanics by finite element method, and the continuity equation is discretized in the fluid flow domain by finite volume method. Solving this coupled set of equations, the displacement of solid and pore pressure can be obtained.

In the actual simulation of reservoir exploition, the fluid flow should only be simulated in the reservoir area, while the geomechanics need to be investigated in the whole computational domain up to the ground in order to fully capture the effect of stress and strain change on fluid flow. Thus the flow domain is typically a subset of the geomechanics domain. In some coupled analysis, additional computational domains are added above and below the reservoir area known as overburden and underburden in order to better capture the stress field. However, these extra domains significantly increase the computational cost of simulation. Moreover, how large area of overburden and underburden is needed to fully capture the stress change still needs further investigation.

In order to improve the computational efficiency of coupled analysis when overburden and underburden computational domains are included, a FEM-FVM method using high resolution for fluid flow domain is proposed in this paper. The advantage of the presented method is that different computational grids could be used for finite element method and finite volume method. The grids used in finite volume method are set up by meshing inside the finite element grids for fluid flow domain. Therefor numerical simulation of fluid flow can be carried out in finer resolution for reservoir domain when geomechanics simulation will be carried out in coarser grids. Since the geomechanics component causes most of the calculation burden, this method can significantly improve the efficiency of the whole simulation. Several numerical examples are presented to show accuracy and efficiency of the proposed method.

References

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