A Finite Volume Technique for Treating the Geomechanics-Fluid Flow Coupling in Porous Media

Gustavo G. Ribeiro[†] and Clovis R. Maliska[†]*

[†]Computational Fluid Dynamics Laboratory - SINMEC
Mechanical Engineering Department
Federal University of Santa Catarina
Florianópolis, SC, Brasil, 88040-900
ggrbill@sinmec.ufsc.br, maliska@sinmec.ufsc.br
http://www.sinmec.ufsc.br

ABSTRACT

The numerical simulation is an important tool for the prediction of oil and gas production of a petroleum reservoir. For better predictions all the important physical phenomena should be considered during the simulation, and the rock mechanics of the porous rock is one which most influences the oil production. Therefore, the prediction of the porosity and permeability of the medium coupled with the fluid flow is of great importance in petroleum reservoir simulation.

The flow-generated pressure field changes the reservoir stress and strain states, and those changes, if not controlled, can close wellbores and even fully damaged the well, especially when the pressure drops too much near the well. In this work it is considered the Biot's theory of consolidation [1] for deriving the governing equations of the geomechanics and Darcy's equation for the fluid flow. It is usual to have these problems solved using different numerical tools, being the finite element method the choice for the geomechanical problem, while the finite volume method is employed for the porous media flow. There are also methodologies using solely the finite element method for both problems, but, in general, in this case, mass conservation and force balances are not conserved at discrete level.

In this paper both problems, fluid flow and geomechanics, are solved using the EbFVM – Element-based Finite Volume Method, a cell vertex method in the framework of unstructured grids. The methodology herein advanced is mass conservative, an important characteristic for the numerical solutions of fluid flow problems, and also ensures the exact force balance for the discrete geomechanical problem. The use of the same mesh for both problems avoids interpolation when transferring data among problems. Pressure and displacements storage is done in a co-located fashion on the grid.

The problem is solved in a two-way coupling [2] with a segregated approach, whereby the solutions of each problem exchange information in all time steps. This strategy is employed to ensure that the appropriate time step in the numerical solution for each physic involved is used, rendering stability for the whole scheme. Two classical problems, the poroelastic column and Mandel's problem, whose analytical solutions were used to validate the models, are solved. Previous results obtained using this methodology with Cartesian grids and staggered arrangement [3], showed excellent results. The extension of the scheme to general unstructured grids is realized in this paper.

REFERENCES

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