Nærbrønnsimulering - Biannual report 2011

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Biannual report 2011

Project 6349

The aim of the first stage of this project was to determine the preferred discretization method for near-well simulation in 3D. We started out expecting that the L-method should be well suited for these simulations. However, the results so far, do not give any clear advantage for the L-method over the O-method. For instance, for near-well simulation on hexahedral grids in a homogeneous and anisotropic medium the L-method is generally better than the O-method; for a heterogeneous domain with anisotropy (with no wells and gridded with hexahedrons) with small aspect ratio, the O-method is better; however, for the previous case with high aspect ratio, the L-method seems slightly better.

We have clearly observed limitations of the methods with respect to anisotropy, aspect ratio of grid cells, and perturbation of grid cells. Hence, we have also investigated a symmetric version of the

MPFA O-method. This method requires an only-tetrahedral grid. It gives unconditional convergence for all cases. The disadvantage is that it requires a mesh of only tetrahedra, and thus increases the number of elements compared to a grid of hexahedra. Further, it produces a very wide cell stencil.

Further investigations of the MPFA-methods to clarify the above limitations and the possibly develop an adaptive method that uses the best method for the given case, will be carried out by A. Stephansen.

We have started a collaboration with the group of Eymard at IFP in France. The aim of this collaboration is to compare the MPFA method to a gradient scheme developed at IFP. This scheme is called VaG (Vertex approximate Gradient) and is unconditionally symmetric for any

type of grid cells. It also produces a small cell stencil. The drawback is that it does not have an explicit expression for the flux.

We (C. Guichard, a PhD-student at IFP and myself) have started to write a paper on this comparison, and hope to finish this during the next months. After finishing this paper, I will proceed to the next stage of the project, namely extension from single phase to multiphase flow.

A summary of the work done during the period 1.1.2011 - 1.7.2011:

- **Further development of gridding**: A filter has been generated to import 3D grids from FVCA6 benchmark website and to write grids on the format of the benchmark site. Further, work has been done to generate only-hexahedral near-well grids. The difficulty is the connection between the near-well region and the outer grid..

- **Near-well case**. In this case we investigate a slanted linear well in a homogeneous and anisotropic medium. We have used both our own grids, and grids available at the FVCA6 (Finite Volumes for Complex Applications) benchmark site. The investigations are performed by comparing with an analytical solution on sequences of refined grids. For only-hexahedral grids, the L-method worked well for a large range of anisotropies. However the range depended on the well angle. The O-method worked for a smaller range of anisotropies. For hybrid grids consisting of pyramids, tetrahedrons and hexahedrons, the L-method did not work. The O-method converged for a range of anisotropies, but the behavior was not as good as for only-hexahedral grids. For only-tetrahedral grids, the O(1/4)-method is symmetric and converged for all cases investigated. The L-method do not work on tetrahedra. Further tests will be done to investigate other well directions compared to the principal direction of the permeability and the main direction of the grid cells. It could also be interesting to consider grid perturbations and or -compressions.

- **Heterogeneous case:** In this case, we investigate a domain consisting of two layers. Each layer has a homogeneous but anisotropic permeability. The domain is heterogeneous since the permeability is different in each layer. We focus primarily on hexahedral grids, but we have also considered tetrahedrons, prisms and pyramids. For no grid-compression (size of cells are the same in each direction), the L-method had convergence problems for very small grid perturbations and or anisotropies. The O-method worked well. However, for grid compression (aspect ratio 20 or 50), the L-method worked better (surprisingly), and the O-method had convergence problems.

  Also, we investigated the influence of different boundary conditions. We considered two types of Dirichlet conditions and the Neumann condition. There were clear differences in accuracy with respect to the type of boundary condition used. And, in some cases, we observed differences in convergence behavior. The behavior was different for flux and pressure and the Neumann condition was best for flux and the Dirichlet was best for pressure. We also investigated the cell-wise error to check whether the error occurred near the boundary or not; but no clear conclusion could be drawn.

- **Aspect ratio and LGR:** We would like to investigate if locally refined grids can improve the near-well simulation when the aspect ratio of the grid cells become large. However, we found that the analytical solution for the cases we had considered was not well suited. And no other suitable analytical solution is currently known. Hence, currently a conclusion must be postponed. Further work might be to develop another analytical solution, or to run cases with no analytical solution, and only compare the difference between the methods. This will at least give an indication if differences exist.

- **MPFA methods for different element types**. To get more information on the MPFA-methods related to element types, we investigated convergence behavior on grids of tetrahedrons, prisms and pyramids, in addition to the hexahedral grids. We considered only mainly unperturbed grids, but the domain was heterogeneous and anisotropic. For the tetrahedral grids, the L-method did not converge. For all the other grids, the O-method was slightly better than the L-method (that is, it converged for a larger range of anisotropies).

- **Tracer flow.** As mentioned above, we would like to compare the MPFA methods to the VaG-scheme. However, the VaG-scheme does not have an explicit flux. (It is still locally mass conservative, and the sum of fluxes entering a node can be computed). One method to compare the accuracy of the fluxes of the MPFA and VaG scheme, is to investigate the behavior of the methods for tracer flow. Currently this comparison is ongoing work, and the simulations will be performed using the multiphase simulator at IFP.