V161-P010 Room: Poster Session Hall Time: May 17

Simple numerical method for simulating underground multiphase flow

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The author proposes a simple numerical method for simulating underground flow of water and steam and presents a few calculations. Numerical simulation of underground multiphase flow is one of important techniques for understanding hydrothermal systems qualitatively. This technique is useful for not only predicting the underground flow of mass and enthalpy but also obtaining the essential constraint in geophysical and geochemical studies by solving coupled problems (e.g., with change in gravity and self potential, transportation of chemical species, etc.).

Today, using the ready-made simulators is the most practical way for carrying out the numerical simulation of underground multiphase flow. This is because the conventional numerical method for solving the governing equations is too complicated for nonprofessional programmers to develop their own softwares. We cannot solve the problems with arbitrary conditions and coupled effects unless we develop a simulator by ourselves.

The author proposes a simple explicit method for integrating the governing equations with time whereas the implicit method has been used widely. The conventional implicit method requires to solve a system of nonlinear equations by using Newton-Raphson method. The number of unknown variables is identical with the product of the number of grid points and that of unknown parameters (e.g., pressure P and enthalpy h). On the other hand, the proposed method only consists of substitutions and solving a system of nonlinear equations with up to two unknown variables. We can develop our simulators with easy programming by using this method. The fault of this method is to require much longer execution time than the implicit method even if we adopt parallel computing. This is because the available time step in the explicit method is longer than that in the implicit method by several orders of magnitude. However, taking into account the total cost from the development of the software to obtain the valid solutions, the proposed method is worth using.

The author carried out the numerical simulations of transient and steady state problems by using the proposed method. In addition to the parallel computing with a PC cluster containing eight CPU cores, we adopted multigrid method for solving the steady state problem. The results were consistent with that of the calculations carried out by using HYDROTHERM version 3.1 (Kipp *et al*., 2008).