XVIII International Conference on Water Resources
CMWR 2010
J. Carrera (Ed)
CIMNE, Barcelona 2010

NON-ISOTHERMAL EFFECTS ON MULTI-PHASE FLOW IN POROUS MEDIUM

A.K. Singh[*], W. Wang[*], C.H. Park[*], U.J. Goerke[*] and O. Kolditz[†*]

[*] Department of Environmental Informatics
Helmholtz Centre for Environmental Research – UFZ, Permoserstr. 15, D-04318 Leipzig, Germany
e-mail: ashok.singh@de, web page: http://www.ufz.de

[†] University of Technology Dresden, Germany

Summary. Non-isothermal multi-phase flow model for the numerical simulation of heat and mass transfer processes in a porous media is used in various fields of technical applications. It is characteristic of such compositional models that they consider the flow of more than one fluid phase and the transport of components in the fluid phase. Multi-phase flow processes are strongly dependent on non-isothermal effects, in particular when vaporation/condensation plays a dominant role.

Here, we injecting liquid water in a partially saturated porous media which voids of the skeleton are filled with hot gas, thus we have a three-phase system. The gas phase is considered as a mixture of ideal gases composed of dry air and water vapor. Components of gas phase are considered as two miscible species through diffusion. Heat transfer is accounted through conduction, convection as well as latent heat transfer. Coexisting fluid and solid phase are assumed to be in local thermal equilibrium and works done by density change of the fluids are neglected. The resultant mass transfer due to vaporization exhibits a great impact on distribution of water saturation. Vapor pressure therefore offers a comprehensive image of the complexity in this thermo-hydro coupled behavior.

Theoretically, the thermo-hydro coupled processes in geological porous media are governed by the mass and energy conservation laws of the continuum mechanics. The governing equations written at macroscopic level are based on averaging procedures the averaging approach of the mixture theory are commonly used to establish the governing partial differential equations, which is suitable for understanding the microscopic behavior of the porous media. The primary variables are capillary pressure, gas pressure and temperature along with a large group of material parameters and constitutive relations, such as the saturation vapor pressure, heat of vaporation, water saturation and diffusion coefficients etc.

The established numerical model is highly nonlinear with the resulting FEM matrix equation. The macroscopic balance equations are discretized in space and time within the finite element method. In particular, a Galerkin’s procedure is used for the discretization in space and the Generalized Trapezoidal Method is used for the time integration. The numerical model is implementation in the frame work of the open-source scientific software GeoSys/RockFlow, which is based on object oriented programming (OOP) techniques. This example has been simulated to emphasize the importance of non-isothermal effects on distribution and evolution of water saturation.