Sensitivity of Results of the Water Flow Problem in a Discrete Fracture Network with Large Coefficient Differences

M. Hokr, J. Kopal, J. Březina, P. Rálek

This work deals with modelling of groundwater flow in a compact rock with network of discrete fractures. In a real system, it means the flow in a system of 2D planes (polygons) in the 3D space, in our 2D model problem (cross-section) it means the flow in s system of lines (abscissa) in 2D plane. The flow is governed by the Hagen-Poiseuille Law, which simply means potential flow with the coefficient (hydraulic conductivity) proportional to the width of the fracture (aperture for geologists) to the power of three.
The fracture network of the models is usually stochastically generated. The resulting problem has the features that large variations of the aperture and conductivity exist and that several very small fracture segments e.g. when three fractures cross just aside from a single point. This leads to the differences of the coefficients in the linear equations system from the finite elements up to ten orders of magnitude, with the consequence of numerical instability.
We compare two different numerical methods and simulation codes. The commercial NAPSAC using standard linear finite elements is one of the typical tools used by hydrogeologists for fractured rock problems. The code FLOW123D developed at the Technical University of Liberec (authors' group) uses mixed-hybrid finite element method with the flux mass balance by definition.
The test problem consists of 7797 fractures divided to 60052 segments. The agreement of results is quite unevenly distributed from percents for most of the values to difference in orders of magnitude in few exceptions. The main difference is in the total mass balance error which is about 10^{-1} for NAPSAC and 10^{-5} for FLOW123D. The mentioned values with the large error are smaller contribution to the total flux and are comparable with the mass balance error, which is an argument for our code as more credible.