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Numerical Method for the Multi-Dimensional Groundwater Flow Analysis in Fractured-Porous Medium with Topography

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ABSTRACT

Numerical analysis program based on flow resistance theory is developed for the multi-dimensional analysis of flow and mass transport through fractured-porous medium. Numerical algorithms for detecting fracture intersections, fracture connectivities are introduced and inter-block flow resistances within fractured-porous medium are evaluated. The overall calculation process is shown in Fig. 1(a) and related numerical methods are as follows :

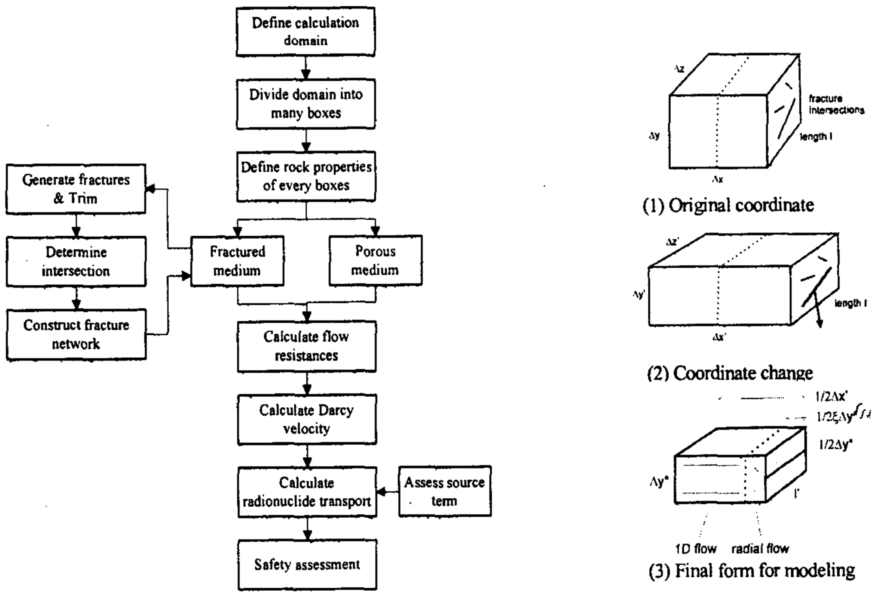
The program is developed on the basis of finite volume method assuming steady-state, constant density groundwater flow. The domain for calculations is defined using various cuboid blocks with an overall cubic structure. Within the overall region, each blocks are specified one of the following ones : an inactive medium, a fractured one and a porous one. The non-planar top surface description is achieved by specifying some blocks to be inactive in such a way that the remaining active blocks approximate the desired domain. In this way, various geometries can be described with non-planar sides or even with one or more holes in the interior of the domain.

Every fracture is described in the form of rectangular plate with various sizes and properties. In order to describe those characteristics of fractured rocks the stochastic methods are adopted in generating various fracture. The algorithm is suggested to reduce time-consuming processes in detecting intersections and connectivities between fractures. Inter-block flow resistances are calculated at every intersection between fractured mediums or porous mediums or porous medium and fractured medium. In order to evaluate inter-block flow resistance values for a staggered grid arrangement,

fluxes are stored at cell walls and scalars at cell centers. The balance of forces, i.e. the Darcy law, is utilized for each control volume centered around the point where the velocity component is stored. The transmissivity (or permeability) at the interface is assumed to be the harmonic average of neighboring blocks. Flow resistance theory was utilized to relate the fluxes between the grid blocks with residual pressures. The flow within porous medium is described by three dimensional equations and that within an individual fracture is described by a two dimensional equivalent of the flow equations for a porous medium.

In order to assess the inter-block flow resistance between porous medium and fractured one some mathematical assumptions are adopted in dealing with flow division between fractures, anisotropy of transmissivities at intersections and flow pattern description. On the basis of these assumptions the inter-block flow resistances are successfully described in a fractured-porous medium. Related modeling process is described in Fig.1(b). Newly proposed models would contribute to develop numerical techniques concerning flow and mass transport analysis in fractured-porous rocks.

Key words: Flow resistance, Fractured-porous medium, Control volume method, Multi-dimensional analysis, Topography



(a) (b)

Fig. 1 (a)Overall calculation process and (b)flow resistance evaluation process in fractured-porous medium