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A Numerical Investigation of Stress Heterogeneity in Fractured Rock Masses

Xiao Wen Duan (2), Jing Zheng (1), and Kun Liang (1)

(1) Petro China Research Institute of Petroleum Exploration and Development, Department of Resource Planning, China (zhengjing123@petrochina.com.cn), (2) PetroChina Exploration and Production Company

In a natural reservoir, the majority of hydrocarbon is hosted in fractured rock masses. Under in-situ stresses, the interactions of fractures contribute to the heterogeneity of stress in the rock matrix, which can potentially cause a change of matrix pore volume and lead to the variations of fluid flow behaviour of reservoirs.
The heterogeneity of mean stress in matrix block as well as its potential impact on the variability of permeability is investigated numerically by using the combined finite-discrete element method (FEMDEM) bases on the Virtual Geoscience Simulation Tools (VGeST). The fracture-induced mean stress heterogeneity is modelled by applying various in-situ stress states to a rock mass which contains a network of natural closed pre-existing fractures observed from geological mapping. Then the geometrical and mechanical information (i.e. fracture displacement, rock mass deformation and stress components, etc.) is extracted by using the two-dimensional FEMEDEM code, Y2D, to calculate the geomechanical response to the applied boundary stresses .After determining the possible heterogeneity of mean stress caused by the presence of fractures, the extent of the stress-induced reduction in permeability is investigated by applying a relationship between permeability and mean stress obtained from the literature.
The results for stress heterogeneity in different rocks under different far-field stress conditions indicate that the fracture behaviours dominate the heterogeneity of mean stress in rock masses, and the influence of rock material properties on mean stress heterogeneity is not strong, especially when a relatively low far-field stress is applied at the model boundary together with a low stress ratio. However, the heterogeneity of mean stress has a relatively strong response to high in-situ stress a high stress ratios. The statistical analysis shows that the mean stress values fit well with the “t location-scale” distribution. Based on the numerical data, this investigation of the stress-dependent matrix permeability indicates that the influence of mean stress on permeability in the matrix rock is generally likely to be insignificant. However, in some extreme case (e.g. mean stress=60MPa), the reduction of permeability can reach approximately 50%, which means there is a significant response to mean stress increase in some local area.