Imam Khomeini International University
Vol. 4, No. 4, Winter 2020, pp. 8-11

نشریه مهندسی منابع معدنی
Journal of Mineral Resources Engineering (JMRE)

DOI:10.30479/jmre.2019.10143.1236

Numerical Study of Effective Parameters on Fluid Leakage from UCG Extraction Stopes

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(Received: 27 Feb. 2019, Accepted: 19 Jun. 2019)

Abstract: Gas leakage through the cracks and tracks surrounding Underground Coal Gasification (UCG) is of criteria affecting the feasibility of economic methods of the UCG reactor. In terms of process control and groundwater contamination capacity, the sealing of the UCG reactor is very important. Various factors affect the gas leakage from the UCG reactor. In this paper, the parameters of pressure, temperature and joint characteristics (including opening, length and intensity) as the most important factors affecting gas leakage through rock mass fractures are examined using numerical modeling. For this purpose, The Mazino Tabas coal area is studied as a case study. The DFN-FRAC3D computer program is used to stochastically simulate joints and create an equivalent pipe network. Also, Water Gems software is used for flow analysis. The results are shown that increasing the reactor pressure and increasing the rock mass jointing around the reactor increases the flow rate and the gas leakage. On the other hand, increasing the reactor temperature does not have a significant effect on the output flow rate. Besides, jointing is the most effective factor in fluid leakage through the UCG reactor. Among the geometrical features of the joint, including the intensity, the opening and the length of the joint, the joint intensity factor has been introduced as the most important factor.

Keywords: Numerical modeling, UCG، DFN, Equivalent Pipe network, Gas emission.

INTRODUCTION

Underground coal gasification (UCG) refers to the process of converting in-situ coal to gas products. One of the most significant problems in UCG is gas leak resulting from the extraction site and its outreach to the ground surface or groundwater resources. In this paper, the factors affecting this issue are investigated to evaluate gas leak. According to the literature, so fat, the contribution and effects of each of these factors on the amount of gas leak have not been quantified. Factors affecting gas leak in UCG include: gas compositions, pressure, temperature, gasification rate, porosity, thickness of slag, water content ofgroundwater level, and primary and secondary joints. Some of these factors are controllable and others are not.

In this study, using research data acquired from field operation in Mazino area, a 3D model of a Discrete Fracture Network (DFN) is provided by DFN-FRAC^{3D} software to create its equivalent pipe network model. Finally, a hydraulic model of the area is analyzed using the Water Gems software to determine the amount of gas leak. Then, sensetivity analysis of the results are performed based on pressure, temperature and joint parameters.

METHODS

Discrete Fracture Network (DFN) is the most known method of modeling discontinuous behavior of fluid flow in the joint rock area. DFN assumes that the rock matrix is impermeable and the fluid can flow only through the joint network. When the rock matrix permeability is low, this method is preferred [1]. In many geological structures, stone matrix permeability is very small compared to the permeability of fractures in the rock mass and fractures are the mainstream of the fluid flow.

Here, the equivalent pipe network is created based on DFN model. Each fracture plate has the traces of all the intersecting fractures. Equivalent pipes are made by connecting the center of the lines in the plate. İn each fracture plate, the pipes are connected from the midpoints of the line to create a pipe network. Then, diameter of the equivalent pipe is calculated for each joint (Figure 1).

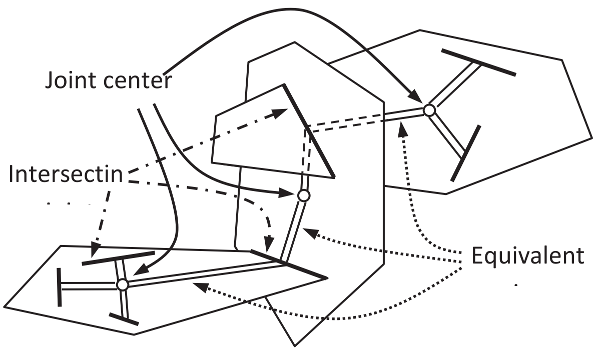


Figure 1. Schematic view of converting joints into a pipe network

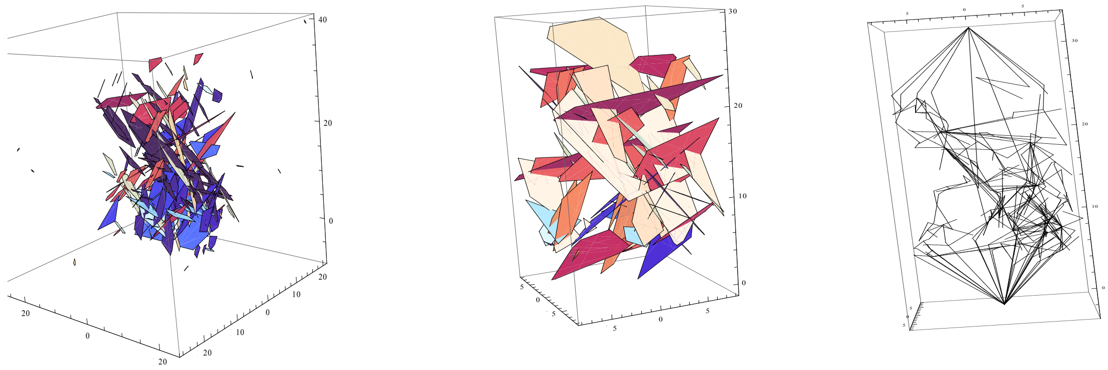
As they have no effect on the fluid flow, isolated joints can be eliminated in DFN. The hydraulic model: in order to analyze the pipe network, the commercial Water Gems software is employed. Before starting the flow modeling process, numerical outputs of the DFN-FRAC^{3D} software need to be entred into the Water GEMS software. Two reservoirs are defined at the start and end points of the network and a suitable pump is provided for supplying the reservoir pressure at the beginning point.

FINDINGS AND ARGUMENT

Figure 2 shows an example of implemented DFN, a network of connected joints identified, and an equivalent pipe network model. In this model, intersecting pipes with upper and lower boundaries are connected to two points via the virtual pipes. These virtual pipes are assumed to have no friction so they don’t effect the results of hydraulic analysis. In this way, the pressure/suction head is applied on the first point and measured at the second point.

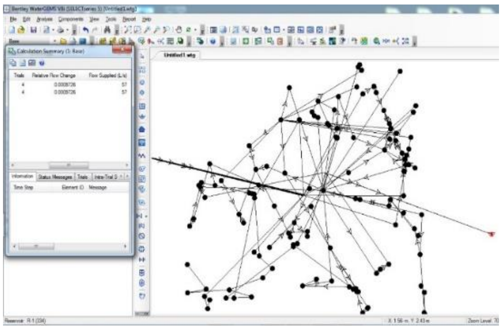
In the case of the Mezino area in Tabas, due to large number of formed pipes, the Representative Elementary Volume (REV) modeling is performed.

Five cubic sample sizes of 3, 5, 8, 10 and 15 m are considered. Based upon REV size, the estimated average flow rate of the studied rock mass is 212 lit/s (Figure 3).

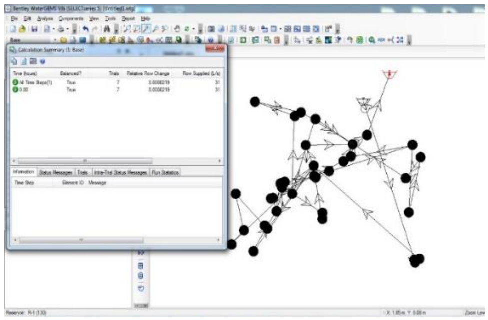


(A) **(B)** **(C)**

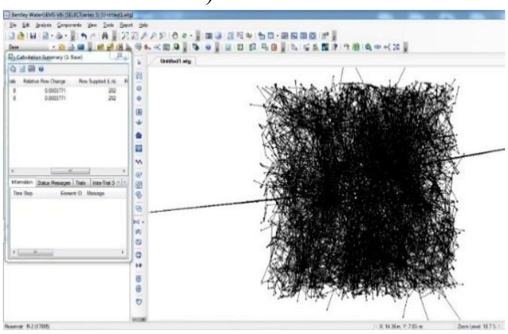
Figure 2. A) A joint network with all the available joints, B) A connected joint network (conductor), C) An equivalent pipe network



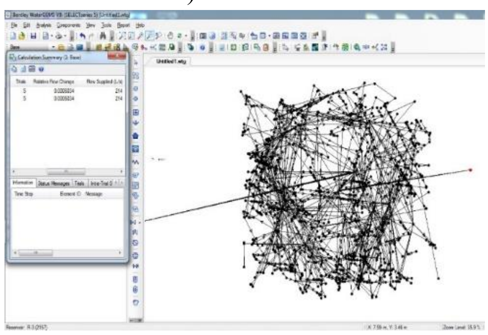
B) 5*5*5 m^3



A) 3*3*3* m^3



D) 15*15*15 m^3



C) 8*8*8 m^3

Figure 3. Results of flow analysis by Water Gems software

FINDINGS

According to the analysis, it is concluded that pressure, temperature, and jointing system are of most important factors contributing gas leak from the rock mass. Among the joint properties, opening in the first place, and then, (spacing) intensity and joint length are the main effective parameters in fluid leak. Results of the study are presented in Figures 4.

CONCLUSIONS

According to the results obtained it can be concluded that:

- Increasing in the fluid or reactor pressure increases the flow rate or gas leak so the flow rate curve varies depending on the pressure follows normal distribution.

- Increasing in the fluid or reactor temperature has no significant effect on the intensity of the outlet flow so the flow rate curve varies depending on the temperature follows uniform distribution.

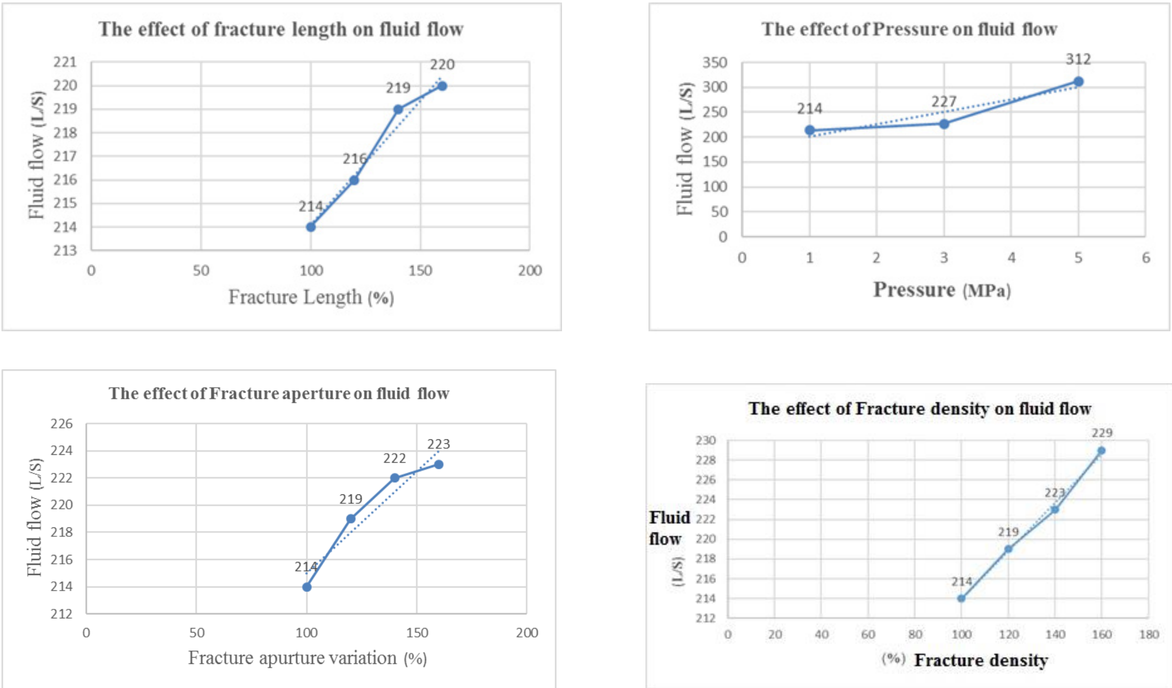


Figure 4. Derived from the research findings

- Aggravated jointing intensity (i.e. the number of joints) is the main cause of fluid leakage so it has a significant effect on the outlet flow rate and its leakage.
- Increasing in the joint opening means increases both diameter of the equivalent pipes and fluid transfer capacity. The flow leakage will be increased by increasing in the joint opening.
- Increasing the length of joints means that the joints are more likely to collide with each other and consequently more joints are included in the conductive joints. Based on the performed modeling, it has been proven that increasing the joint length increases the gas leakage rate.
- Also the curve of flow rate with respect to joint intensity, joint opening and joint length follows the normal distribution.

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