Groundwater Dynamics Method of Mine Discharge and Its Parameter Analysis

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Abstract. Mine discharge refers to the total amount of surface water, fissure water, old kiln water and karst water inflow into the mine roadway. It is an important indicator in the process of coal mine production safety, and also the focus of scholars' attention. Based on a large number of previous research results, this paper introduces the groundwater dynamic method of mine discharge, analyses the parameters in the theoretical formula, discusses the influence of the change of parameters on mine water inflow, and provides a reference for further understanding the calculation of mine discharge.

Introduction

Mine discharge refers to the amount of water flowing into the mine, roadway and roadway system in a unit time from development to mining. It is one of the important indexes to determine the hydrogeological type and complexity of hydrogeological conditions of ore deposits and to evaluate the economic and technological conditions of ore deposit development. It is also the main basis for drawing up the mine dewatering design scheme and determining the production capacity. At the same time, it will have a serious impact on the mine production safety. Therefore, accurate prediction of mine discharge is of great importance to the design of water-proof and drainage systems and the prevention of flooding wells. The occurrence of malignant accidents in coal mines and ensuring the safety of production in coal mines are of great significance[1].

Up to now, analytical method, also known as groundwater dynamics method, is the most common method used in the calculation of mine discharge. If the ratio of length to width of a pit is less than 10, it can be regarded as radiation flow, and the complicated inflow boundary can be generalized into a "big well" for calculation, which is called "big well" method. This method is suitable for calculating the inflow of water into various types of tunnels and tunnels, and also for solving the inflow of water from some specific dewatering devices. At the same time, it can also provide important indicators for the design of dewatering, such as dewatering time, dewatering range and dewatering water level. This method is relatively simple and has good effect[2]. If the ratio of length to width of a mine is greater than 10, it can be regarded as parallel flow and transformed into "horizontal corridor", collectively known as "corridor" method. In this paper, based on the previous research results, the "big well method" in groundwater dynamics of mine discharge is introduced in detail, and its parameters are analyzed, in order to provide reference for relevant researchers to engage in the research of this subject.

Analytical Method of Steady Flow

The "large well method" can be divided into two categories, namely, the steady flow analysis method and the unsteady flow analysis method. The calculation model of actual mine water inflow is shown in Figure 1. Aquifers are generally confined aquifers. When the water level in the well is lower than the aquifer roof, an unconfined flow zone will appear near the well and become a confined unconfined (diving) well.
According to Dupuit's hypothesis and Darcy's law, confined water is transferred from confined water to non-confined water when the distance between wells is \( r = a \). The formula for calculating steady flow of confined-unconfined water is as follows:

\[
Q = \frac{1.366K(2HM - M^2 - h^2)}{\lg R_0 - \lg r_0}
\]

According to the above pressure-free calculation formula, firstly \( H = 459.76 \text{m} \), \( M = 21.80 \text{m} \), \( R_0 = 1000 \text{m} \), the radius of "big well" is \( r_0 = 700 \text{m} \), the variables are \( h \) and \( K \), and \( H = 0-37 \text{m} \); \( K \) is 0.0010m/d, 0.0011m/d and 0.0012m/d, and the Q-h curve shown in Fig. 2 can be obtained. It can be seen from Fig. 2 that Q decreases with the increase of \( h \); at the same water column height, Q increases with the increase of \( K \). Fixed \( H = 459.76 \text{m} \), \( h = 37 \text{m} \), \( R_0 = 1000 \text{m} \), \( r_0 = 700 \text{m} \), the variables are \( M \) and \( K \), \( M = 21.80-600 \text{m} \), \( K = 0.0010 \text{m/d}, 0.0011 \text{m/d} \) and \( 0.0012 \text{m/d} \), the Q-M relationship graph shown in Figure 3 can be obtained. From Figure 3, it can be seen that Q and M are parabolic, Q increases with the increase of \( M \) when \( M \) is lower than \( H \); when \( M \) is equal to \( H \), mine discharge value is the largest; when \( M \) is higher than \( H \), Q increases with the increase of \( M \).

Maqingshan et al. took the water inflow prediction of Bayannao Mine as an example, and used the analytic method to predict the water inflow of 2-1 coal seam in the pre-mining area. The prediction results have some errors with the actual water inflow.

When the mining dynamic water level falls below the floor, the value of \( H \) is generally negligible, and the calculation formula can be simplified as follows:

\[
Q = \frac{1.366K(2HM - M^2)}{\lg R_0 - \lg r_0}
\]

If the aquifer in the mine is homogeneously distributed and the natural water level is approximately horizontal, the reference influence radius \( R \) can be calculated by the following formula:
According to the pressure-free formula and the formulas mentioned above, the fixed head value \( H \) is 459.76m, the aquifer thickness \( M \) is 21.80m, the radius \( R_0 \) of the “big well” is 798m, and the height \( h \) of the water column is 37m. Variables are water level drawdown \( S \) and permeability coefficient \( K \), \( S \) values are 0~423m, \( K \) values are 0.001m/d, 0.005m/d and 0.010m/d. The Q-S curve shown in Fig. 4 can be obtained. As can be seen from the figure below, the water inflow \( Q \) decreases with the increase of \( S \), and \( Q \) increases with the increase of \( K \) at the same water lever.

![Figure 4. Q-S curve](image)

Formula: \( Q \) is mine discharge, m³/d; \( K \) is permeability coefficient, m/d; \( M \) is aquifer thickness, m; \( S \) is water level drawdown, m; \( F \) is mining area, km²; \( R_0 \) is the reference influence radius of aquifer, m; \( r_0 \) is the "big well" radius, m; \( r \) is the influence radius, m; \( H \) is the water head value calculated from the bottom plate of the aquifer thickness or confined aquifer, m; \( h \) is the height of the wellbore water column, m.

### Analytical Method for Unsteady Flow

When the mine drainage is larger than the water-filled aquifer recharge, the groundwater movement is always in the unsteady flow state in the initial stage of mining or in the case of horizontal extension of mining during the construction process, and the condition of relative stability can not be achieved. Only the unsteady flow method can objectively calculate the mine discharge.

The formulas for calculating unsteady flow are as follows.

\[
Q = \frac{ST}{0.08W(u)} \quad \text{(Theis formula)}
\]

When \( u \) is less than 0.01~0.1, Jacob's formula for calculating water inflow can be obtained.

\[
Q = \frac{ST}{0.183} \sqrt{\frac{2.25Tt}{r^2u}}
\]

In the formula, \( Q \) is flow rate (water inflow), m³/d; \( S \) is wellbore water level drawdown, m; \( T \) is water conductivity, m²/d; \( r \) is wellbore (water inrush) radius, m; \( u \) is water release coefficient; \( t \) is the duration of pumping (draining) water, d.

When \( u \) is less than 0.01~0.1, according to the Jacob formula mentioned above, firstly, \( T \) is 45 m/d, \( S \) is 323 m and \( r \) is 1 m. The variables are \( t \) and \( u \), \( t \) is 0.00069~0.009d, \( u \) is 0.0001, 0.0002 and 0.0003, and the Q-t curve shown in Fig. 5 can be obtained. Secondly, the fixed \( T \) is 45 m/d, \( S \) is 323 m, \( t \) is 0.008d. The variables are \( r \) and \( u \), \( r \) is 1~10m, \( u \) is 0.0001, 0.0002 and 0.0003. The Q-r curve
shown in Figure 6. Fig. 5 shows that Q decreases with the increase of t, and Q increases with the increase of u at the same time. From Figure 6, we can see that Q increases with the increase of r, and Q increases with the increase of u at the same radius of influence.

Huajieming [5] used Jacob formula of unsteady flow analysis method to predict mine water inflow from coal seam floor water inrush. It was found that this method is more applicable in theory, more flexible in operation and more intuitive in calculation results. Cui Yuanping and Zhang Baoping [6] used steady flow analysis to predict the water inflow of pomegranate mine in Jinsha County, Guizhou Province, and evaluated the results, and put forward some reliable suggestions. Frontier [7] The analysis method is used to predict the water inflow in Wuju Coal Mine, and the results show that the accuracy of the analysis method is high.

Conclusion

Analytical method and numerical method are the most commonly used methods for predicting mine discharge. Analytical methods include steady-flow analysis and unsteady-flow analysis: in steady-flow analysis, Q increases with the increase of water column height when other parameters are fixed, while Q increases first and then decreases with the increase of aquifer thickness; in unsteady-flow analysis, Q decreases with the increase of T and R with the increase of other parameters unchanged. Increase and gradually increase. Analytical method is generally applicable to mining areas with simple hydrogeological conditions, while numerical method includes finite difference method and finite element method.

Reference

[1] Zuo Wenchao, Wang Binhai, Cheng Zihua, Zhang Yaobin. Summary of mine discharge prediction methods [J]. Chemical minerals and processing, 2016, 45 (09): 71-74.
[2] Cui Jie. Review on calculation method of mine discharge [J]. Hydraulic coal mining and pipeline transportation, 2009 (04): 1-4+95.
[3] Ma Qingshan, Luo Zujiang. Comparisons between analytical method and numerical method in predicting mine discharge[J]. Mining safety and environmental protection, 2015, 42 (04): 63-66+71.
[4] Shi Xinyuan, Ruan Zhaosen, Wang Shijie, et al. Handbook of Water Supply Hydrogeology [M]. Beijing: Geological Publishing House, 1983.
[5] Huajieming. Analytical method of unsteady flow for calculating mine discharge [J]. China Coal Geology, 2010, 22 (10): 38-40.
[6] Cui Yuanping, Zhang Baoping. Application and evaluation of analytical method in prediction of mine discharge [J].Groundwater, 2016, 38(05): 8-9+76.
[7] Frontier. Prediction of mine discharge in Wuju Coal Mine [J]. Geology of Jilin Province, 2018, 37 (03): 51-54.