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Study on the Model Test of Fault Lagging Water-inrush in Deep Mining Floor

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Abstract Under conditions of deep mining, water inrush from Taiyuan coal seam floor fault of Northern China type coal mine is quite different from shallow mining, it is commonly characteristic with delaying water bursting and its water inflow volume can be increasing gradually, which is mainly due to the characteristic of fault fracture zone and the high pressure of floor. This paper selects the faults (fracture zone) with different characteristics, using model-test method to analyze the rule of fault water inrush under different pressure with different properties of the fault. It is showed that the change of deep fault water inrush mainly due to two aspects: one is the characteristic of fault with itself different properties; the other is the evolution laws of fault when it is seepage channel in different stress conditions. The change of seepage channel is the foundation of seepage flow pattern transformation, which can lead to dynamic change of water inrush volume. The research findings provide hydro-geological basis for coal floor water inrush prevention and control in deep mining condition.
Keywords deep mining, fault delaying water bursting, model-test method, seepage flow pattern transformation, seepage channel evolution laws

Introduction

Water inrush of lower group coal mining in Northern China type coal field has closed relation with faults in mine area. Study shows that the amounts of water inrush of coal seam floor fault occupy more than half of the total, and it has varied types. According to the location and form of water inrush, Wang Zuoyu and Liu Hongquan (1993) classified fault-age's water inrush into four types, namely: burst type, hop type, buffer type ,delay type . And they summarized the characteristic of fault-age's water inrush and fault evolution.

Among the floor fault-age's water inrush types, direct exposure type of water-bearing and water conductive fault, mining influence type, commonly the intervals between water inrush and mining activities is not very long, the main type of water inrush is burst type, hop type, buffer type. However the delaying water bursting of water conductive fault generally occurs after the mining activities in days, months and even years. Why the same fault-age's water inrush has different forms? Many scholars have done research on it. Based on physical and mechanical tests of fault fracture zone materials, Wu et al.(2002) and Wu et al.(2003) found the relationship between water content, confining pressure, load characteristics and fault fracture zone materials, and propose new concept of weaken effect of floor water inrush time. Situ tests were conducted on fault water resisting ability of rock mass by Wu et al.(2003), it is concluded that the water resisting strength of rock in fracture zone is general smaller 3~10 times than complete rock. Shi et al.(1992) conducted mechanical analysis when fault gouge is separate confined water, from mechanism to study the delay type water inrush. In addition, from the perspective of the fault activation in mining face, Li et al. and Shi et al.(2004) made studies on different types of water inrush.

Through the above analysis, we known that for the studies on mechanism of mining work face floor fault water inrush is mainly from the perspective of water resisting strength of fault fracture zone materials and fault activation, for the impact mechanism of high pressure water seepage in the fault zone and changes in porosity on fault delay type water inrush, the research is few.

In order to lucubrate study the mechanism of fault water inrush in high water pressure, reveal the change laws of water inrush volume. By the model test method, simulating water inrush process of different fault in the high water pressure conditions. Obtaining the change laws of water inrush volume and its channel during water inrush processes, play a guiding role on the prevention and control of fault water inrush in high pressure water.

Model design

Analysis of simulation prototype

Simulation prototype is F1 fault in 4302 working face of one coal mine. The fault is a normal fault with NW dip and 65°dip angle, the fault fall is 13 m and the width of fault zone is 5~10 m. Fault zone is filling with fault breccias, fault gouge and pulverized coal. As shown in fig 1.

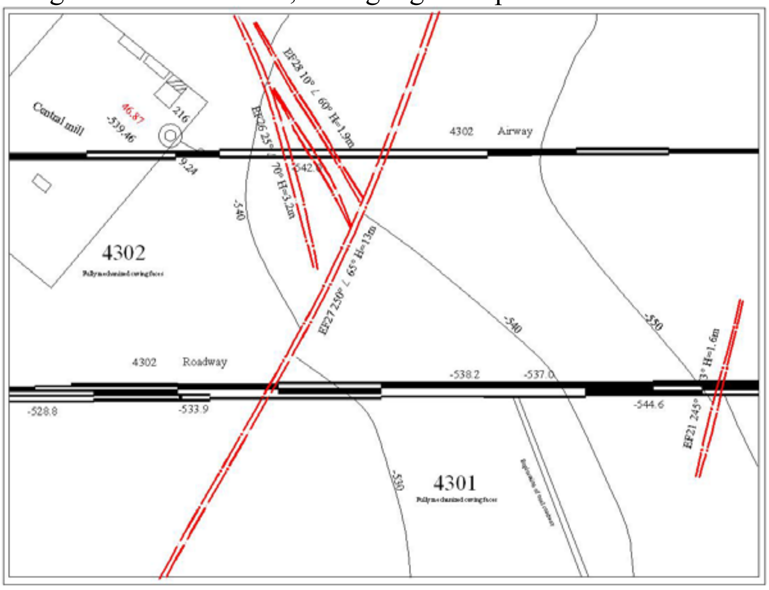

Fig. 1 *The sketch map of NO.1 fault in NO.4 mining field*

The simulate fault is shown in fig.2. Water inrush accident did not happen when airway and roadway of working face get through the fault reveal F1 fault is poor of water.

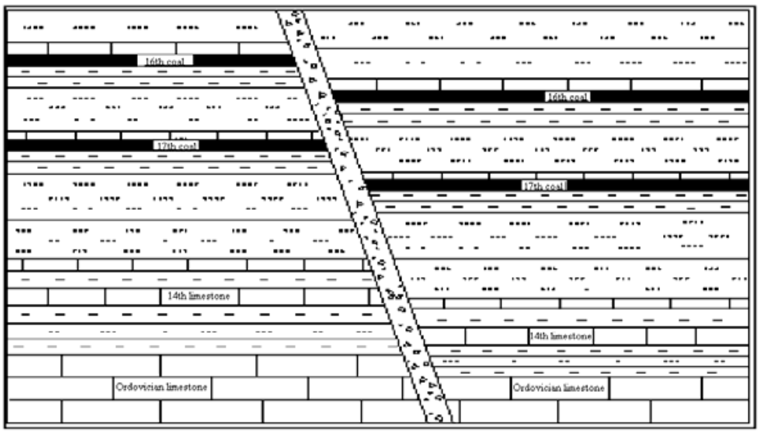

Fig. 2 *The sketch map of prototype fault in model test*

Test Design

(1) ***Model Design***

According to the fault exposed by tunneling roadway, conducting field sampling of fault fracture zone materials, the main parts of the selected sample are gray or gray-dark fault breccias and fault gouge. After the scene sealed, we do indoor uniaxial compressive test, analyze clay mineral composition and grain size analysis test of fault gouge in laboratory, sample's water content and density also be tested, the test provide the basis for model simulation. According to the field sampling, volume ratio of gray fault breccias and fault gouge is 3:2.

According to comprehensive drilling columnar figure, hydro-geological exploration hole O2-5 shows that the distance between 17^{th} coal and Ordovician limestone is 65.68 m, water pressure of the Ordovician limestone is 6.89 MPa. So in accordance with proportion of 1:100 to design model, seen in fig 3. High water pressure fault water inrush model consist of two parts: dynamic compression device (high pressure mud pump, type TX-500) and simulation of fault water inrush channel device.

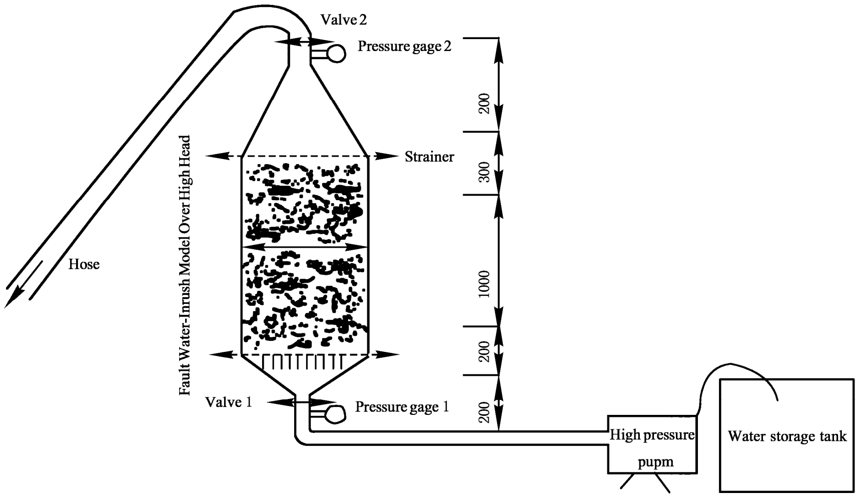

Fig. 3 *The sketch of fault water-inrush model over high head*

(2) The experimental design

This model is to simulate the processes of fault water inrush: In the mining process of 1# fault, because of the destruction of floor aquifuge by mine pressure and the of floor Ordovician limestone high-pressure confined water, the effective thickness of floor is reduced. When the working face is advancing near to fault, it can occur the Ordovician limestone water inrush of floor high-pressure confined water. As shown in fig. 4.

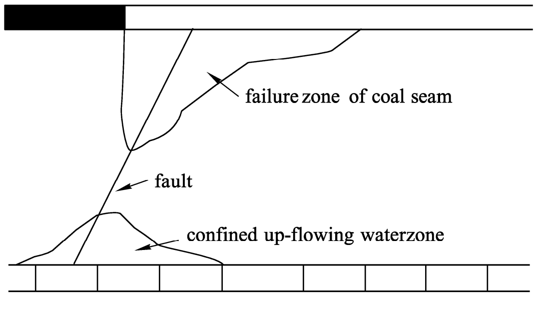

Fig. 4 *The sketch of Mining fault water-inrush*

(1) ***The test design process***

① Gravel, sand and clay were added in the main water seepage device, simulating 1# fault in 4 mining area. The expanded test is change the different proportion of the three materials, simulating the fault fracture zone of different mechanical properties (extensional, compression and torsion).

② To exert pressure on the model, simulating the aquifer of Ordovician limestone by high-pressure pump, the value of pressure increase from 1Mpa to 5 MPa. In the process of applying each pressure, measuring the change of highlight water yield in a specific time to seek the law and relationship between pressure and water yield.

③ With the change of pressure, the change of water yield is closely linked to the permeability of simulated fracture fault zone. Seeking the relationship between pressure and permeability, discharge and permeability by tests.

(2) ***Brief introduction of the test process***

① According to the fracture fault zone to matching the gravel, coarse sand and clay, making the fillings well-distributed into the simulation device, ramming it, simulating 1# fault-an extensional fault in 4 simulation area.

② In accordance with the order of orthogonal test table, making the fillings saturated with water firstly, turn off the valve, when the water pressure up to the test pressure, turn on the valve, keeping the pressure is constant, measuring the gushing water and the coarse sand and clay which are emergent with gush in the same interval.

③ Changing the ratio of gravel, sand and clay, repeating the process of ① and ②.

Analysis of the test result

According to the original data by experiment to calculate parameters, such as the seepage velocity, Re, porosity and so on. Though the variation of parameters to analysis the transformational rules of seepage in water inrush process.

Identification and analysis of the flow

According to the relevant theories of fluid mechanics (Xue 1997), it can be decided that in porous medium seepage, the fluid flow is laminar and accord with Darcy′s law when the Reynolds test data $R_e \leq 1\sim10$. Based on experiments some scholars obtained the critical Re of laminar flow conversion to turbulent flow is 100~300, the critical Re obtained by Pavlov is 7~9.

According to the results of R_e calculated by the model test, the following conclusion can be obtained. The three faults in simulated fault all have a certain stage at the beginning of water inrush process, and they are all accord with Darcy′s law, here can be said Darcy flow. For example the water inrush pressure P_w of 1# fault is 3 MPa in 20 seconds, 2# fault is 3 MPa in 40 seconds and 5Mpa in 20 seconds, 3# fault is 3 Mpa in 80 seconds and 5 Mpa in 60 seconds, seen in fig. 5~7.

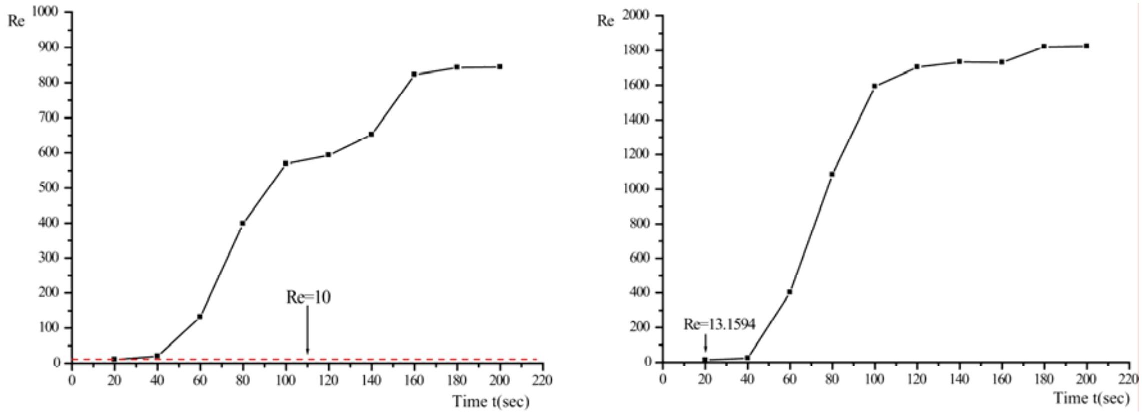

Fig. 5 *R_e -curve of No.1 fault water inrush (P_w =3, 5 MPa)*

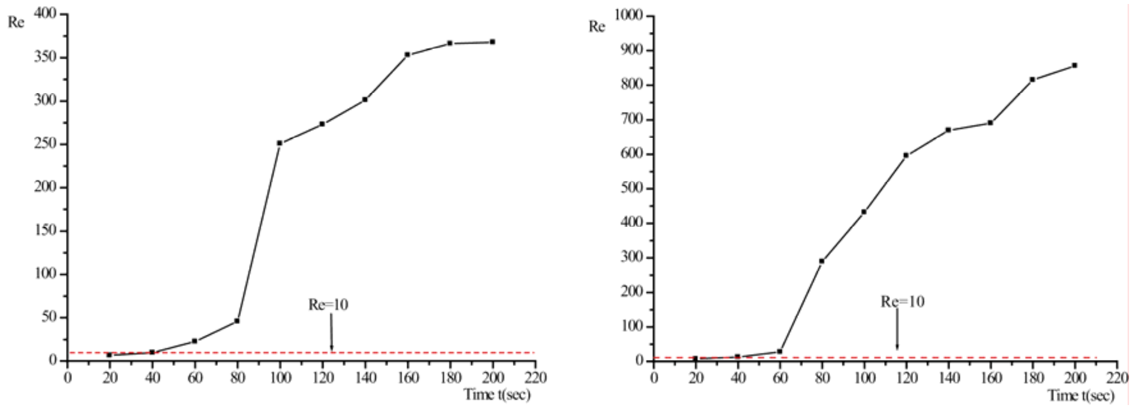

Fig. 6 *R_e -curve of No.2 fault water inrush (P_w =3, 5 MPa)*

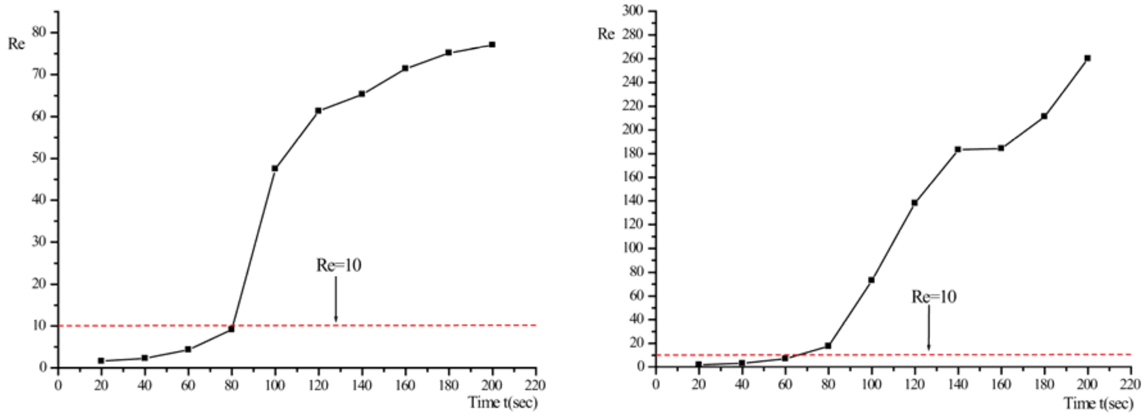

Fig.7 *R_e -curve of No.3 fault water inrush (P_w =3, 5 MPa)*

The change rule of water inrush quantity (Q)

In the process of simulating fault water inrush, the amount of water is constantly changing in a certain period, the rules are as follows:

(1)In the early stage of the water inrush, the water volume is small, with the constantly scour of fault fracture zone by the confined water and hole enlargement, the water inrush quantity (Q) begin to increase, when the mud, sand and other fine in the fault fracture zone were washed off, due to water inrush channel no longer changes, the growth of water inrush quantity (Q) tends to be stable, no longer increase by leaps and bounds. As shown in Fig. 8~10.

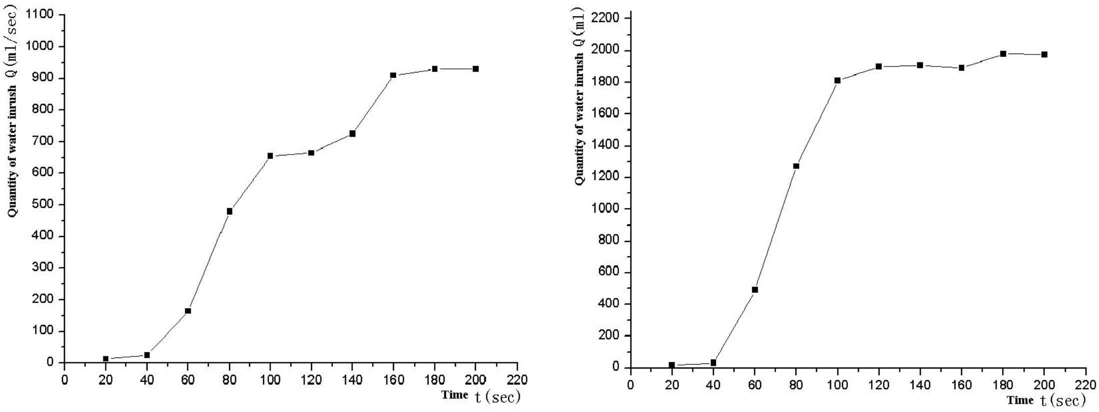

***Fig.8** Q -curve of No.1 fault water inrush (* P_w =3, 5 MPa*)*

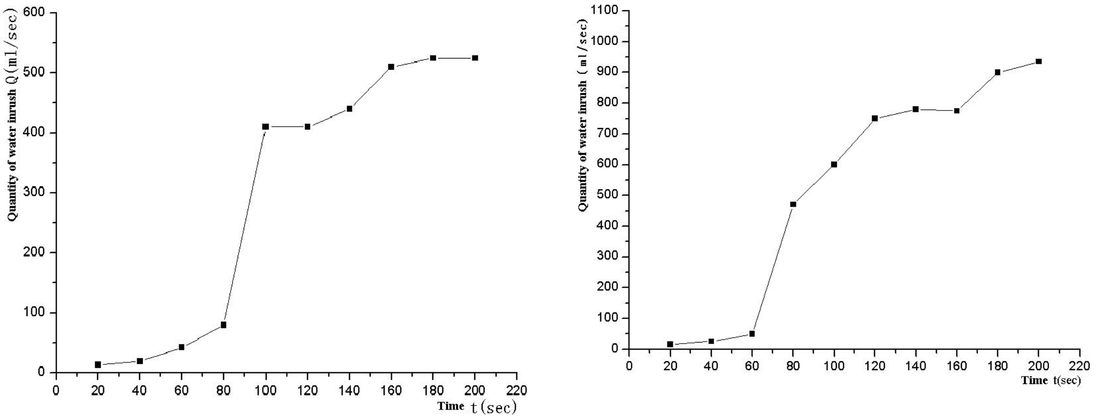

***Fig. 9** Q -curve of No.2 fault water inrush (* P_w =3, 5 MPa*)*

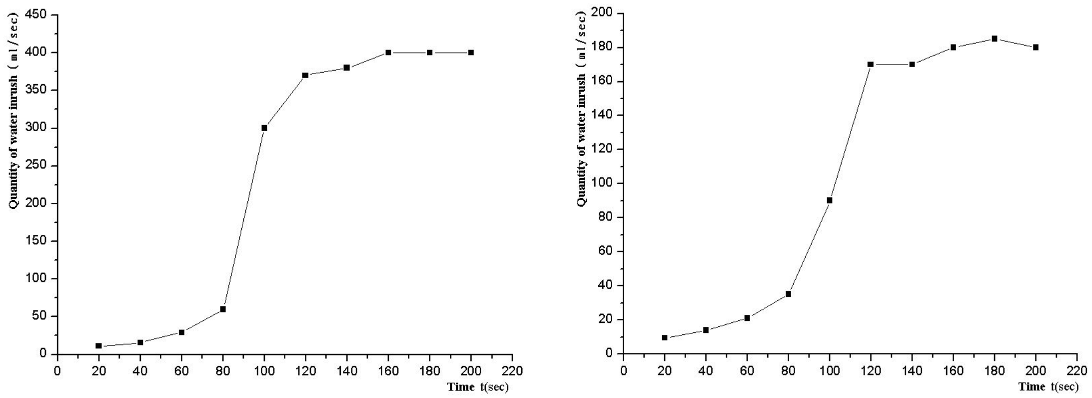

***Fig. 10** Q -curve of No.3 fault water inrush (* P_w =3, 5 MPa*)*

(2) In the curve of *Q-t*, each curve has sharp increase of water volume, in the corresponding time period, the change of filtration mode leads to the change of the amount of water. Such as: in 1#Fault, at the moment of 60 s and160 s in the condition of 1 MPa; at the moment of 40 s and100 s in the condition of 3 MPa; at the moment of 40s and 100 s in the condition of 5 MPa, they are the change points of pore flow-fissure flow, fracture flow-pipe flow respectively. In 2# Fault, at the moment of 80 s and 100 s in the condition of 1Mpa; at the moment of 80 s and 100 s in the condition of 3 MPa; at the moment of 60 s and 80 s in the condition of 5 MPa, they are the change points of pore flow-fissure flow, fracture flow-pipe

flow respectively. in 3# Fault, at the moment of 80 s and 120 s in the condition of 1 MPa; at the moment of 80 s and 100 s in the condition of 3 MPa; at the moment of 60 s and 80 s in the condition of 5 MPa, they are the change points of pore flow-fissure flow, fracture flow-pipe flow respectively.

The change rules of the air void

In the process of simulation of water inrush, due to the constantly scour of fault fracture zone by the confined water, the micro fractures or air void in Fault zone is expanding, the fine grained material such as mud and sand are out of the fault zone, large fractures in water inrush channel will turn into the pipe when the mud and sand is out of the fault zone completely. The change of the air void that in fault fracture zone is expressed on the change of the void-age (n) directly.

(1) In a certain period of time, with the passage of water inrush time, the void-age (n) is increasing constantly, it shows that the composition of air void is changing. Namely the air void undergoes the process of voids or micro fractures- fractures-large fractures or pipe. As shown in fig. 11~13..

(2) It is similar to the change of the Reynolds and the water inrush quantity, with the increase of water pressure, the void-age is also increasing.

(3) With the increase of water inrush time, the mud, sand in the fault fracture zone is out of the fault zone, the fillings in the fault fracture zone and the water inrush channel are no longer change, the porosity tends to be stable.

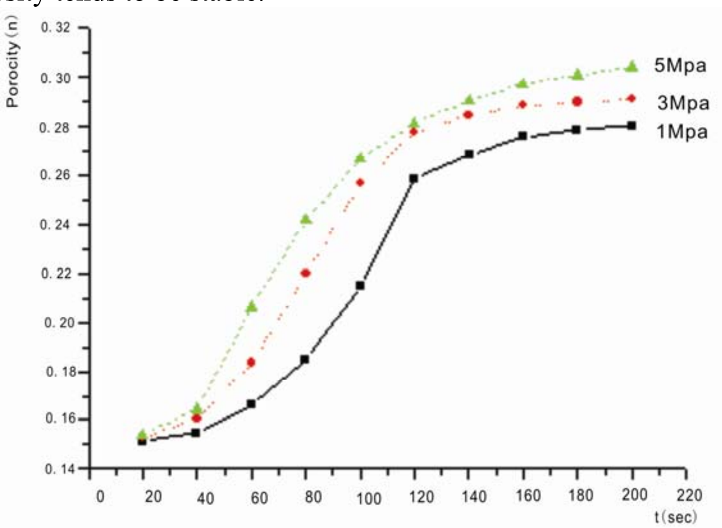

Fig. 11 *n-curve of No.1 fault water inrush under different pressure*

Summary

(1) This paper aimed at diversity and complexity of water inrush from fault form in the north China type coal mine, in-depth analysis of the characteristics of water inrush, proposed the difference of water inrush way under the similar conditions of water inrush depending on the differences in confined aquifer water inrush channel - fault zone.

(2) Conducting field sampling of fault fracture zone materials, the main parts of the selected sample are gray or gray-dark fault breccias and fault gouge. After the scene sealed, we ddi indoor uniaxial compressive test , analyze clay mineral composition and grain size analysis test of fault gouge in laboratory, sample's water content and density also were tested. The test

provided the basis for model simulation. According to the field sampling, volume ratio of gray fault breccias and fault gouge is 3:2.

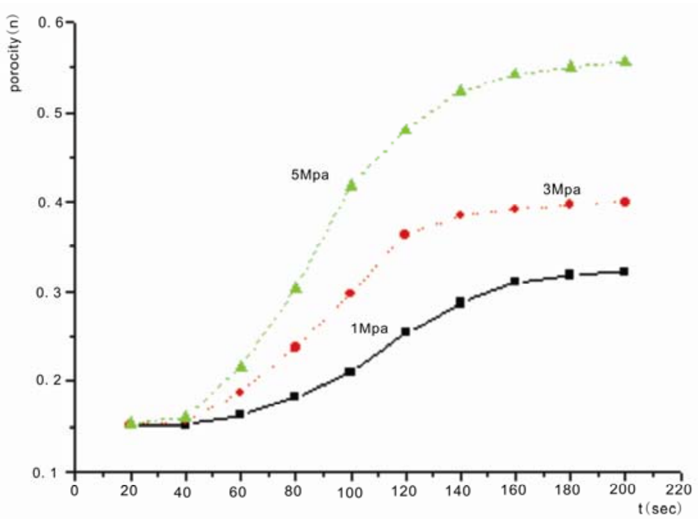

Fig. 12 n*-curve of No.2 fault water inrush under different pressure*

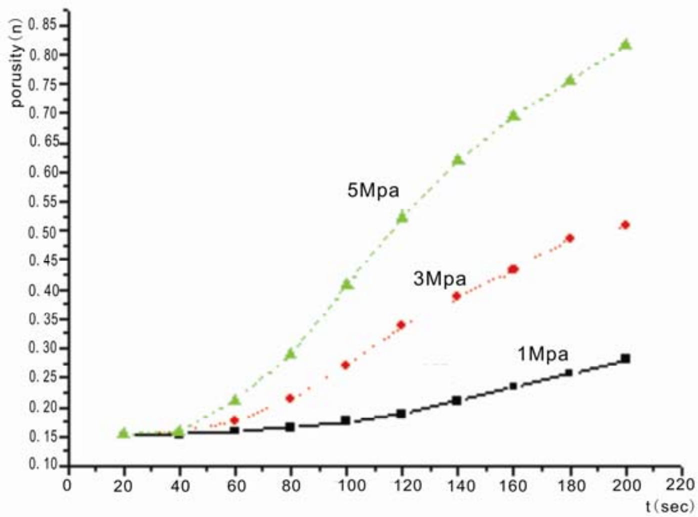

Fig. 13 n*-curve of No.3 fault water inrush under different pressure*

(3) The similarity theory and dimensional analysis was used to design fault water inrush model of the high pressure water.

(4) Three kinds of models and nine tests were disigned to simulate different types of fault water inrush processes of the high pressure water. Through the model test, the change curve of R_e, Q, n in the process of water inrush was obtained and relevant information was analyzed.

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