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Numerical simulation study of spontaneous combustion in goaf based on non-Darcy seepage

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Abstract

In order to study the influence of non-Darcy seepage on spontaneous combustion in goaf, seepage tests were conducted in three groups of broken rocks which were different average particle sizes, and then the test data were processed by non-Darcy seepage equation. So that the equations of non-Darcy permeability coefficient K with porosity n and particle size d, non-Darcy flow factor β with the n and the d were achieved. On the basis of these equations, the paper analyzed the influential factors of the spontaneous combustion in goaf, and then established the spontaneous combustion mathematical model on the coupling of air flow field, oxygen concentration field and temperature field on moving coordinates. According to the model, the calculating software was programmed by VB6.0 to obtain the oxygen concentration distribution map and the residual coal temperature distribution map in goaf. The results are of theoretical and practical significance to prevent spontaneous combustion in goaf.

Keywords: non-Darcy seepage; spontaneous combustion; numerical simulation; permeability coefficient; non-Darcy seepage factor

1. Introduction

Spontaneous combustion of the residual coal in goaf is one of the severest disasters in coal mine production [1]. Based on the coal oxygen compound theory and the Darcy's law, scholars both at home and abroad have established the spontaneous combustion mathematical model of goaf with immobile coordinates [2-4]. However, this mathematical model is an astable partial differential equation group with

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moving boundary which makes the model very difficult to be solved. In addition, the gas flow in goaf is considered to be non-Darcy seepage. The mathematical model established by Darcy's law will cause certain error. In order to solve these two problems, this paper established the spontaneous combustion model of goaf based on non-Darcy seepage, using mobile coordinates to deal with the moving boundary problem [5-6].

2. The broken rock percolation test

From macroscopic view, the goaf space is so large that the broken rocks in it can be seen as continuous porous medium for analysis [5]. In goaf, laminar flow coexists with transitional flow and turbulent flow. Therefore, the gas flow in goaf does not completely obey the Darcy's flow. The permeability coefficient is an important parameter for the study of broken rock seepage in goaf, which is related to the porosity and the particle size of broken rock. In order to obtain the fluid seepage law in broken rock, the broken rock percolation tests have been completed with seepage instruments which match MTS815.02 servo-machine [7-9], and then based on the similarity principle of fluid, the law was applied into the goaf.

In the seepage tests, three groups of broken rocks which respectively was the average particle size of 1.125mm, 2.25mm and 4.5mm are used. The same grit rock sample was loaded into permeation apparatus. After that the axial displacements were controlled to make the rock sample porosity respectively reach 0.3, 0.2 and 0.1, and then in each axial deformation three different seepage velocity were set up separately for 3.12×10^{-5}m/s, 6.25×10^{-5} m/s and 9.38×10^{-5} m/s. The test data was shown in table 1. The seepage velocity and the pore pressure gradient, obtained from the same porosity and particle size, was separately done linear fitting and nonlinear fitting. Taking the rock sample of the average granularity 2.25 mm and the porosity 0.2 for example, the fitting curve was shown in Fig. 1.

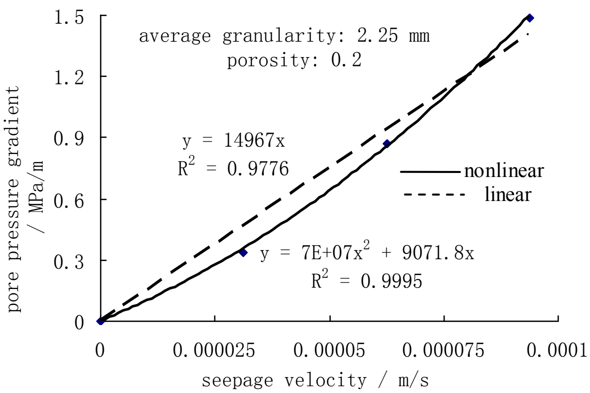

Fig.1 Fitting of seepage velocity and pore pressure gradient

In Fig.1, the correlation coefficient of the nonlinear fitting is bigger than that of the linear fitting, which is proved that the relationship of seepage velocity and pore pressure gradient is more suitable for Forchheimer type non-Darcy seepage equation. The equations from the nonlinear fitting were processed by Formula (1) to obtain the non-Darcy permeability coefficient K and the non-Darcy flow factor β. The specific data are in Table 1.

Forchheimer type non-Darcy seepage equation can be expressed as: