International Journal of Mining Science and Technology 27 (2017) 327–332

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Regression analysis of major parameters affecting the intensity of coal and gas outbursts in laboratory

Geng Jiabo [a,*], Xu Jiang [a,b], Nie Wen [a], Peng Shoujian [a], Zhang Chaolin [a], Luo Xiaohang [a]

[a] State Key Laboratory of Coal Mine Disaster Dynamics and Control, Chongqing University, Chongqing 400044, China
[b] State and Local Joint Engineering Laboratory of Methane Drainage in Complex Coal Gas Seam, Chongqing University, Chongqing 400044, China

A R T I C L E I N F O

Article history:
Received 24 December 2015
Received in revised form 12 February 2016
Accepted 23 June 2016
Available online 21 February 2017

Keywords:
Coal and gas outburst
Gas pressure
Regression analysis
ANOVA
CTA

A B S T R A C T

Estimating the intensity of outbursts of coal and gas is important as the intensity and frequency of outbursts of coal and gas tend to increase in deep mining. Fully understanding the major factors contributing to coal and gas outbursts is significant in the evaluation of the intensity of the outburst. In this paper, we discuss the correlation between these major factors and the intensity of the outburst using Analysis of Variance (ANOVA) and Contingency Table Analysis (CTA). Regression analysis is used to evaluate the impact of these major factors on the intensity of outbursts based on physical experiments. Based on the evaluation, two simple models in terms of multiple linear and nonlinear regression were constructed for the prediction of the intensity of the outburst. The results show that the gas pressure and initial moisture in the coal mass could be the most significant factors compared to the weakest factor - porosity. The *P* values from Fisher's exact test in CTA are: moisture (0.019), geostress (0.290), porosity (0.650), and gas pressure (0.031). *P* values from ANOVA are moisture (0.094), geostress (0.077), porosity (0.420), and gas pressure (0.051). Furthermore, the multiple nonlinear regression model (RMSE: 3.870) is more accurate than the linear regression model (RMSE: 4.091).

1. Introduction

An outburst of coal and gas is defined as the rapid release of a large quantity of gas in conjunction with the ejection of coal from the solid face. Previous studies have recognized that these major factors affecting outburst of coal and gas include stress condition, gassiness of coal seams, geological structures, and mechanical and physical properties of coal based on the hypothesis of comprehensive factors [1]. Incorporating coal mass into a physical model is a very important tool in simulating outbursts of coal and gas [2–5], particularly in evaluating the single factor affecting the intensity of the outburst [6–8]. However, a key challenge is still to understand to what extent the major parameters contributing to the intensity of coal and gas outburst especially considering all these parameters working together [9].

In our study, Contingency Table Analysis (CTA) and Analysis of Variance (ANOVA) were employed to determine the correlation between these parameters and the intensity of the outburst. Two models based on multiple linear and nonlinear regressions were constructed and compared with the prediction of the intensity of the outburst. The remainder of the paper is organized as follows: two models based on multiple linear and nonlinear regressions were constructed and compared with the prediction of the intensity of the outburst. The remainder of the paper is organized as follows: Section 2 introduces the mini-outburst simulation procedure and intensity of outburst-related issues and Section 3 highlights the analysis of CTA and ANOVA. The multiple linear and nonlinear regression models are described in detail in Section 4. The performances of CTA, ANOVA, and regression models are introduced and discussed in Section 5. Conclusions and future research directions are detailed in Section 6.

2. Mini-outburst in coal and gas experiments

2.1. Apparatus and procedure

Coal and gas outbursts with certain stress regimes, gas pressures, and material properties of samples are simulated by a coal and gas outburst simulation device consisting of fast-releasing components, a load-bearing frame, electric self-controlled loading system, reversal unit, main frame bracket, and coal sample molding device as shown in Fig. 1 [10]. Raw coal was crushed, screened, and compression-molded to produce standardized samples under

* Corresponding author.
E-mail address: gengjiabo@163.com (J. Geng).

http://dx.doi.org/10.1016/j.ijmst.2017.01.004
2095-2686/

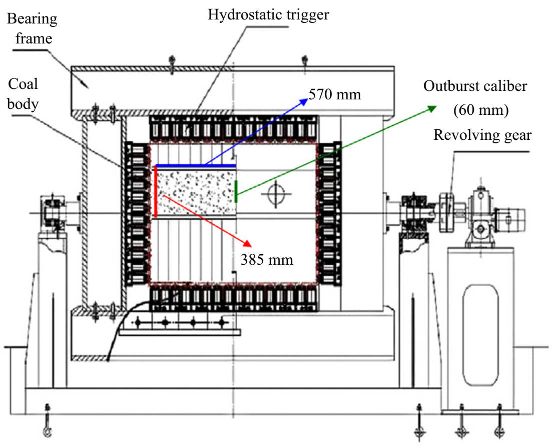

Fig. 1. Structure of coal and gas outburst simulation test-bed.

4 MPa of pressure. Fig. 2 shows the crushing and screening equipment. Seals were installed between the mold and cover before lifting and pasting the mold sealing plate (Fig. 2c). Coal samples were then filled with gas through pressurization in an air tight box (all the gas in our experiments is CH_4) (Fig. 2d). Prior to that an air-tightness test was required for the gas injection due to the 99.99% purity of the experimental gas. Following the airtightness test, a crane (Fig. 2c) is employed to help to install it into the simulator cavity (Fig. 1). Air extraction to form a vacuum is carried out about 2 h before the gas enters. After the gas enters the coal samples, full absorption of gas (about 48 h) was the key step in the experiment. The gas pressure can be adjusted during gas absorption. After that, as shown in Fig. 2d, horizontal load is applied firstly at outburst caliber (P1). The purpose is to prevent the deformation of the coal sample near to the outburst caliber. Then the vertical loads P2, P3, and P4 are applied in order. Finally, to keep the 3D stress stable, another horizontal load P5 is added facing the outburst caliber on the other side. The outburst of coal and gas in the experiment is observed by opening the caliber rapidly. The environmental temperature fluctuates between 18 °C and 20 °C. The whole procedure is illustrated in Fig. 3. Different moisture contents can be produced by adding water before compression of the coal sample. Different levels of geostress can be added by using the hydraulic servo in the form of load as in Fig. 2. The gas pressure can be changed using a pressure control valve on the gas tank.

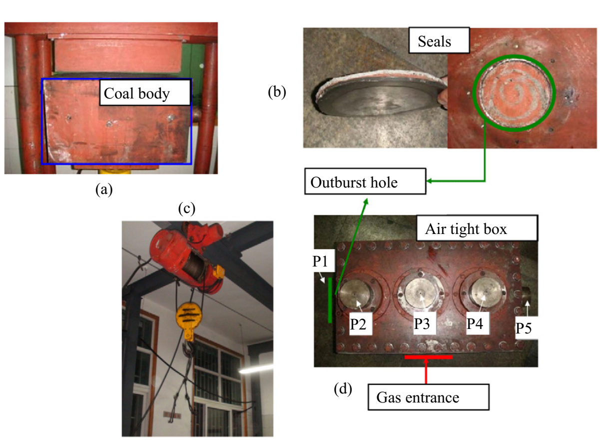

Fig. 2. Key components ((a) compression-molded; (b) seals; (c) cane; (d) air-tight box).

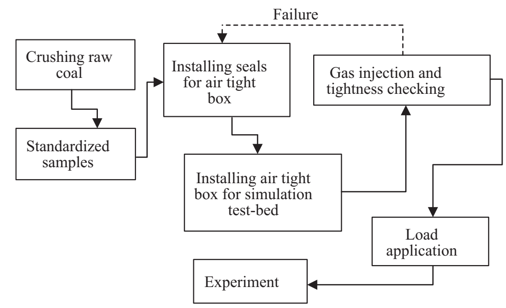

Fig. 3. Flowchart of simulation test of coal and gas outburst.

2.2. Experimental outlines and results

The purpose of experiments is to investigate to what extent the major parameters affect the intensity of an outburst of coal and gas. The investigated object is the relative intensity (*RI*) which means the weight of coal outburst in the total experimental coal mass. The variables in the whole experiment include confinement loading (geostress), gas pressure, moisture, and porosity generated by different initial particle sizes. The experimental arrangement is shown in Table 1.

3. Analyses of CTA and ANOVA

3.1. Analyses of CTA

Contingency Table Analysis is an established test for departure from randomness in materials research and across many scientific fields [11]. Fundamental to this approach is the χ^2 analysis, which is a quantitative measurement of correlation between the respective solutes. The more the measured and expected (random) results differ, the greater the magnitude of χ^2. If the columns and rows of the experimental table are closely associated, then χ^2 will be large, but if there is no correlation between the two variables then χ^2 will be small [12]. However, contentious issues and various rules have been proposed to circumvent this commonly applied restriction [13–15]. Most importantly, if the number of samples is less than 40 and the expected count is less than 5, Fisher's exact test is recommended in place of χ^2 analysis to investigate the hypothesis (in our case the null hypothesis) that these factors have no significant effect on the relative intensity. In our study, the confidence level is defined to be 10%. If p is less than 0.1, the null hypothesis is rejected at a confidence level of 90%, indicating that there is a significant effect from factors. The sample was just 16 and was expected to be no more than 5, thus, the 90% confidence intervals were calculated by exact binomial distribution, and pairwise comparisons were based on the Fisher exact test. The results indicate (as shown in Fig. 4) that moisture (inverse relationship) and gas pressure (proportional relationship) relate to the relative intensity more than geostress and porosity, based on statistical counts. Porosity, especially, has little effect on the relative intensity.

3.2. Analysis of ANOVA

A factorial ANOVA was conducted to compare the effect of different factors on the relative intensity of an outburst for moisture, geostress, porosity, and gas pressure. Table 2 shows a P value of 0.7 for the probability being significantly greater than the significance level, so that the variance of the sample data was the same to meet the prerequisite analysis of variance.