Slurry Feeding to Avoid Ground Subsidence

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ABSTRACT

Subsidence of old abandoned underground mine which are either fully or partially waterlogged occur in the form of depression, cracking of ground, development of sinkholes, potholes etc.. Slurry feeding of mine voids is used to avoid the effects of subsidence on surface structures. The most simple and cost-effective technique is the gravity blind backfilling method, which may be implemented for the filling operation to be carried out over old, abandoned mine workings. However, the field implementation of this method often face problems like premature jamming, inadequate area of filling from one borehole, lack of technological knowledge how to detect the extent of filling along different directions etc.. In most of these cases the field implementation of gravity backfilling technique often leads to unsatisfactory performance due to filling from one borehole stops abruptly without any prior indication. To evaluate pre-jamming indication parameter and pattern of analyses of inlet pressure variation is used, through which change in flow condition was made so that more area can be filled.

Keywords: Abandoned Mine, Gravity blind back-filling, ARIMA model, Pre jamming indicator parameter

1. INTRODUCTION

In earlier days, most coal mines in India have been worked under shallow cover and were practically extracted using Bord and Pillar system of working. Correct records of plans of such workings are generally not available or the plans are not reliable. Over the years, the strength of pillars left as support of the roof has severely deteriorated and frequent collapse of these pillars endanger some important structures and properties constructed above these pillars on the surface due to subsidence [1, 2]. Development of suitable methods to stabilize such areas had been neglected in the past. In this research, studies were carried out on simple gravity hydraulic blind backfilling in a fully transparent scaled model of underground coal mine worked on Bord and Pillar method. The simple gravity hydraulic backfilling has been found to be an equally effective method as slurry pumping or air-assisted gravity backfilling, especially when flow rates are high [3]. An experimental set-up is fabricated to study the process and establish the optimum parameters for achieving maximum sand filling through a single borehole.

2. EXPERIMENTAL FACILITY

To estimate pre-jamming indication parameter, a fully transparent model with water-tight joints as shown in the Fig. 1 is made using 14 mm thick perspex sheets of 4.9 m X 0.4 m size and height of the setup is 0.259 m. Maximum pressure head of the set-up is fixed as 1.5 m. Minimum two [4] borehole is required for this back-filling technique but in the present study one inlet hole and two outlet holes are provided to feed sand as shown in the Fig. 1. The effectiveness of simple gravity blind backfilling from a single borehole depends on parameters like slurry flow rate and sand concentration etc.

3. FILLING PROCESS

Several numbers of experiments have been conducted to inspect critically the filling process and to justify the feasibility of the gravity filling method in the transparent model. The slurry first gravitates down to the open void of the model through inlet pipe of 25 mm diameter. Due to reduction in kinetic energy, velocity decreases rapidly to the vicinity of the inlet and so solid particles drop down from the slurry towards the bottom of the setup and form a conical-shaped heap on the floor. As the height of the heap approaches the roof, narrowing the gap between the roof and the fill material causes an increase in velocity of the slurry. The impact of the input slurry forms a crater at the top of the conical heap just under the bottom of inlet hole.

The turbulence created by the water helps the sand particles to be in suspension and transports them through the narrowed gap between the top of the truncated conical heap and underside of the top cover of the model and finally the particles get deposited along the slope of the conical heap. In this way, the slanted surface of the conical heap advances almost equally in two directions from the inlet pipe. It was observed that front portion of the heap was nearly parabolic and at the beginning, four channels existed, but ultimately after some time three, two and finally only one, channels were present as shown in the Fig. 1. Due to continued deposition, the length of the channel increases and cross-section of the channel decreases, thereby increasing the flow path resistance.

Then a new, shorter route having lower flow path resistance is punctured. In this way continuous meandering of the channels in both directions causes the deposited sand bed to grow in size till the limiting slurry head of 1.5 m becomes insufficient to puncture new alternate route.

When this condition is reached, sudden jamming of the flow path occurs and the filling process ends. In order to test the repeatability of the filling process conducted a few trials were carried out by repeating the same experiment with fixed flow rates and concentrations. It was found that, there is negligible change in sand throughput, although there were some changes present in the path of filling process.

4. RESULT AND DISCUSSION OF PRESSURE SIGNATURE ANALYSIS

Pattern of pressure data

During experiment pressure time data is obtained using DAS. Increasing trend in pressure-time curve provides further evidence that the process indeed non-stationary, so 1st order differentiation of pressure data is taken. Since from auto correlation and partial auto correlation of 1st order the model was not clearly identified so auto correlation and partial auto correlation of the 2nd order pressure-time data is evaluated for model identification. From the nature [5, 6] of autocorrelation and partial autocorrelation one can forecast the nature of curve. From the nature of acf and pacf of the pressure time curve apparent nature of the pressure is ARIMA (0, 2, 1) which can be written as eq. 1.

$$\nabla^2 p_t = (a_t - \theta a_{t-1}) \quad (1)$$

p_t is obtained pressure data in each second from DAS. θ is obtained from initial pattern of pressure data. $\nabla^2 p_t$ is 2nd order backward difference of the pressure-time curve. a_t are generally assumed to be independent, identically distributed variables sampled from a normal distribution with zero mean.

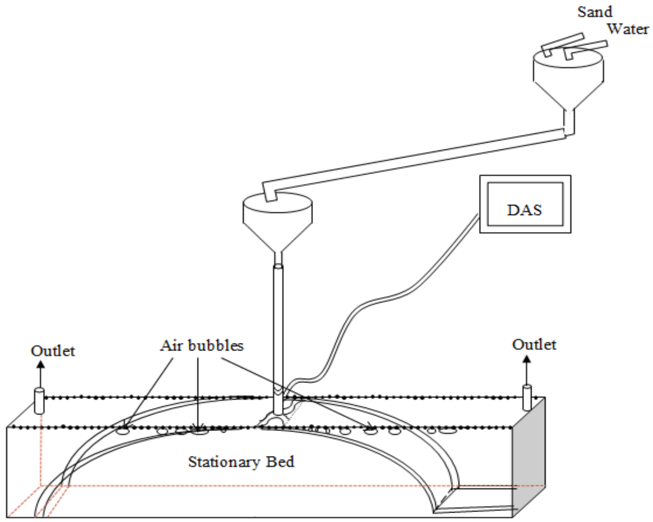


Figure 1: Schematic Representation of Experimental Set-Up and filling process

Jamming Indication Parameter Evaluation

Jamming during experiment is a major issue [7], so evaluation of pre-jamming indication parameter is required. Analysis of pressure signature was carried out to identify a pre-jamming indication parameter by manipulating the pressure-time data in different ways. It may be observed

(Fig. 2) from pressure signatures that the pressure fluctuation in the initial phase of filling is low compared to the same during the final phase of filling. Thus, the entire pressure-time curve can be divided into two sections: Healthy region, and un-healthy region. In healthy region, pressure fluctuations are low, whereas in unhealthy region, pressure fluctuations are comparatively high. It is observed that during filling process some un-natural phenomenon occur before jamming. The coefficient of variation parameter for the entire window of 200 data was chosen to be the only indicator for pressure fluctuations. Then, this fixed window was moved on through the whole experimental data set. The window was moved till the end of the data set to obtain the curve of 'time (sec) vs coefficient of variation'. A cut-off level can be generated based on the coefficient of variation curves, which has increasing trend; cut-off level can be more than 0.06. In the Fig. 2 shows one of such graphs for 20 l/ min of slurry flow rate and sand concentrations of 6%, 10% and 14%.

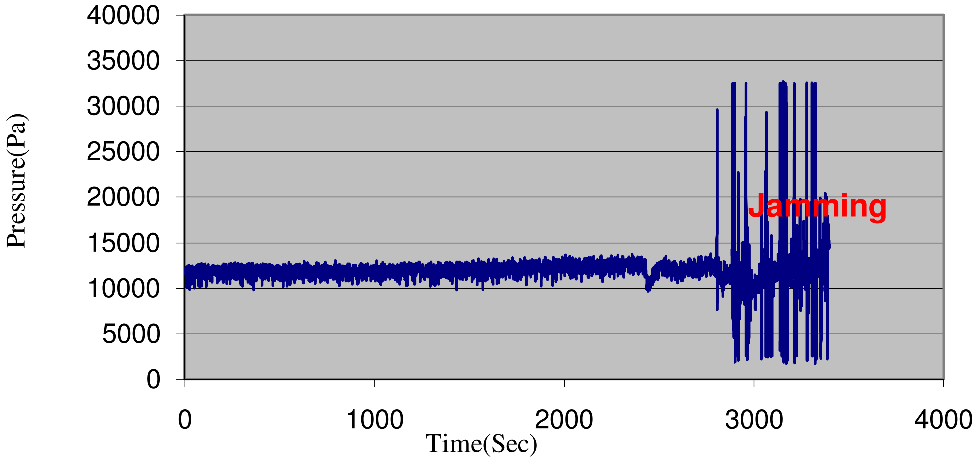
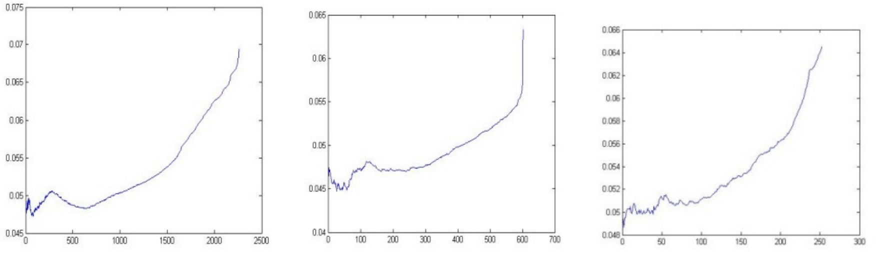


Figure 2: Pressure time curve for 25lpm flow rate and 14% concentration



(a) (b) (c)

Figure 3: Graphs of coefficient of variation of inlet pressure for 25 l/ min flow rate (a) 6%, (b) 10%, (c) 14% concentrations.

Although for the flow condition higher flow-rate and lower concentration can fill more area but it takes more time well as it is more costly to fill-up. From the Fig. 3 one can conclude that when coefficient of variation of running window reach the value approximately 0.06 which indicate the occurrence of jamming. For filling up more area it is need to change the flow condition so that filling process can be done from the same bore hole.

REFERENCE

[1] Helm P R, Davie C T, Glendinning S; Numerical modelling of shallow abandoned mine working subsidence affecting transport infrastructure. Engineering Geology, 2013; 154:6-9.

[2] Peng S S; Subsidence and Structural Damages above Abandoned Coal Mines. Surface Subsidence Engineering, Society of Mining, Metallurgy and Exploration, Inc., Littleton, Colorado 1992:27 – 33.

[3] Walker J S; State-of-the-Art Techniques for Backfilling Abandoned Mine Voids. Pittsburgh, PA, US Bureau of Mines 1993.

[4] Gutfeld V, Jacob R, Lien, S H; *Method and apparatus for filling liquid crystal display (LCD) panel*. US Patent 6, 055, 035 (april 2000)

[5] Box G E P, Jenkins J M; *Time series analyses Forcasting and control*. Holden-Day, San francisco, CA 1976.

[6] Bisgaard S, Kulahci M; *Time Series Analysis and Forecasting by example*. John Wiley & Sons, Inc., Hoboken, NJ, Usa 2011.

[7] Pal S K, Mukhopadhyay S B, Panda S, Tripathi A K; *Studies on gravity blind backfilling for ground stabilization above abandoned underground mines*. Korean Rock Mechanics Conference, South Korea 2010:57-71.