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Estimate of the optimum horizontal well depth for gas drainage using a numerical method in the tabas coal mine

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ESTIMATE OF THE OPTIMUM HORIZONTAL WELL DEPTH FOR GAS DRAINAGE USING A NUMERICAL METHOD IN THE TABAS COAL MINE

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ABSTRACT: One of the hazards in underground coal mining operations is the sudden coal gas emission leading to coal outburst. To reduce the risk of gas emissions to enable safer mining, it is necessary to pre-drain coal seams and surrounding strata. According to the experimental data, there exists a relationship between the gas flow from the coal seam and the stress changes in the upper layers above the coal seam. This is achieved by drilling horizontal drainage holes in the coal seam. Phase2 commercial software was used to investigate induced stresses caused by methane drainage operations during mining. The optimum depth of horizontal borehole from the coal face was calculated based on the actual gas production. Results of the numerical simulation showed that boreholes with a minimum distance of 30 m from the coalface provide the optimum gas drainage performance for the underground Tabas Coal mine in the South East of Iran.

INTRODUCTION

Methane drainage operation is carried out in underground coal mining to prevent sudden gas and coal outbursts and to enhance safety. Generally, coal beds possess low gas recovery. When the coal face is mined, a pressure difference is generated between the face and somewhere deep inside the coal bed strata, this results in methane emission into the working face. Gas emission is further facilitated by horizontal and vertical fractures induced by the changing ground stress conditions. This paper is aims to study the depth of the coal bed inTabas Mine in Iran, which is undergoing stress variation due to mining activities. As part of this study the following items were investigated:

- Model development to evaluate the increased load on coal bed due to mining activities,
- Investigation of the relationship between stress and the coal gas emission, and
- Development of an incremental approach to evaluate the methane production for various given stress levels. Tabas Coal Mine is located about 60 km South West of Tabas City where the extraction is carried out by longwall mining. The average coal bed gas content is in the order of 15 m^3/t.

EVALUATION OF COAL BED BEHAVIOR AND SURROUNDING AREAS DUE TO EXTRACTION

To obtain a reliable numerical simulation, the development of a rock mass model was required. Coal beds differ from other traditional sources for methane emission. Also, they behave differently from other rock masses in terms of mechanical properties.

Phase2 Version 7.0 of Rocscience consulting group, (2010) was used to investigate the rock mechanical behaviour. By using this software, changes in strength properties during loading can be measured separately for the rock matrix and weakening areas. The software allows the selection of the model type (e.g. elastic or elastoplastic behaviour of rock under loading conditions) and various relationships between stress and strain are imbedded in the software as shown in Figure 1.

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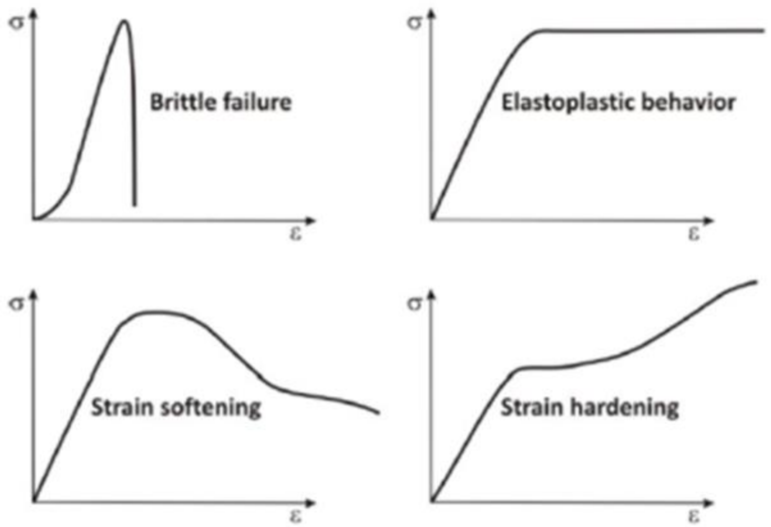

Figure 1: Different types of stress-strain curves for different rock behaviors under various loading conditions

The coal bed of Tabas Coal Mine and its overburden were modelled. The model includes a sandstone layer and coal beds. To simplify the model, these layers were considered to be horizontal; however, inclined and oblique seams were created for simulation by changing the boundary conditions or reconstructing the model. The required mechanical properties (bulk modulus, shear modulus, density, cohesion, friction angle, dilation angle, and tensile strength) and pre-fracture changes of different rocks were collected from information contained in reports provided by Tabas coal mine (Tabas Coal Mine report, 1996 and Shereski, 2005)]. The model is 300 m in width and 200 m in height with 1132 elements. Since the extracting coal bed of Tabas is located 200 m underground, a sandstone overburden was considered at the depth of 200 m in the model. Table 1 lists various relevant coal and sandstone roof properties.

Table 1: Mechanical characteristics of Tabas coal rock and sandstone overburden [6]

Row	Characteristics	Symbol	Values		Unit
			Coal	Roof	
1	Elastic modulus	E	3	3.5	GPa
2	Poisson's ratio	ν	0.29	0.3	-
3	Tensile strength	σ_t	0.66	2.8	MPa
4	Cohesion	C	0.5	4.7	MPa
5	Internal friction angle	φ	23	32	Degree
6	Density	γ	1600	2600	kg/m^3
7	Volume modulus	K	2.38	2.91	GPa
8	Shear modulus	G	1.16	1.34	GPa
9	Dilation angle	V	10	15	Degree
10	Uniaxial compressive strength	σ_c	6.62	25.6	MPa

As Tabas coal was mined by longwall method, the roof was loaded vertically to simulate the shield supports. Figure 2 shows the designed model in the Phase2 commercial software environment.

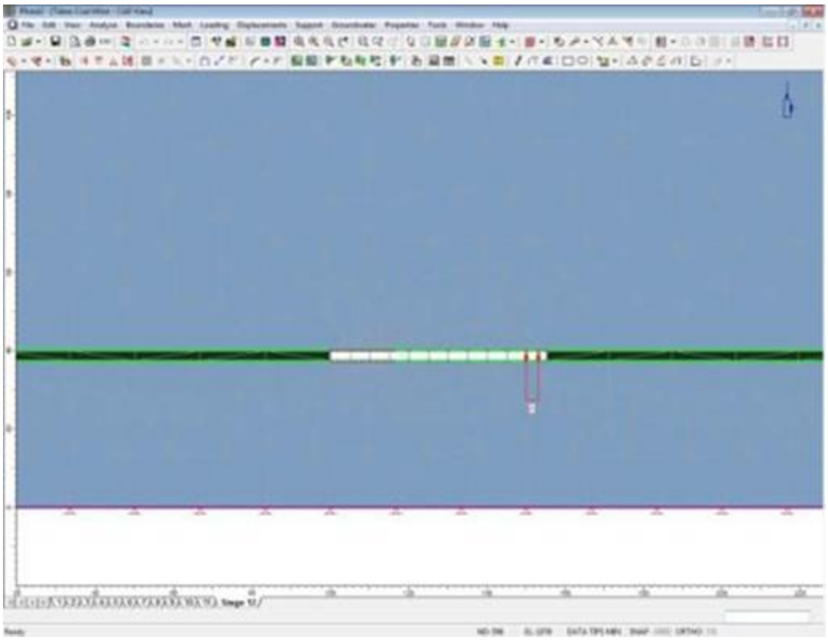

Figure 2: Model of Tabas longwall working panel designed in Phase2

MODELLING OF THE COAL MINING PROCESS AND ITS IMPACT ON INDUCED STRESS AND ABUTMENT LOADS

Dimensions of the caved area were modelled. The goaf zone and movement of strata layers were determined as shown in Figures 3 and 4. Because of mining, stresses existing at different points on the model will change, leading to redistribution of stress in the vicinity of the area of extraction. With increased dimensions of the roof area having less support, the collapse of the goaf zone is thus initiated, which extends up to 30 m from the coalface.

ANALYSIS OF MODEL IMPLEMENTATION RESULTS

After the development of the numerical model and examination of the results, the most important matter to be investigated was stress variations within the coal bed and the roof of the coalface. The immediate or nether roof load is naturally transferred on the hydraulic supports and remaining unmined side coal pillars, resulting in increased load on them. These variations in load are presented in Figure 5. It is clears from the figure that the maximum stress on the free surface of the coalface is almost 8.2 MPa. Also, the amount of loading on the goaf zone will initially be zero but starts to increase at a distance of 20 m from the working face. This increase continues and reaches around 6 MPa on the shield supports, and then develops to the coalface. After that, the amount of load on the coal bed starts to decrease and reaches its initial value of 4.4 MPa after about 60 m inbye of the goaf zone. Figure 4 shows the linearly decreasing trend of stress within the coal seam to the depth of 30 m, and then the stress starts decreasing gently. Since at this distance the stress within the coal bed is somewhere between 5.5 and 8.2 MPa, which is greater than the initial stress, the coal bed gas becomes more concentrated. As a result, horizontal drilling causes a greater pressure difference, leading to higher level of gas release from the coal bed. The normal gas content within the Tabas coal bed was obtained as 15 m^3/t on average, while the amount of emitted gas from the coalface was measured at around 5 m^3/t Tavakkoli, *and sereshkil*,2006 and Najafi, *et al*, 2012). The remaining gas difference (10 m^3/t) enters the goaf zone through a local fracture, due to the high overburden pressure.

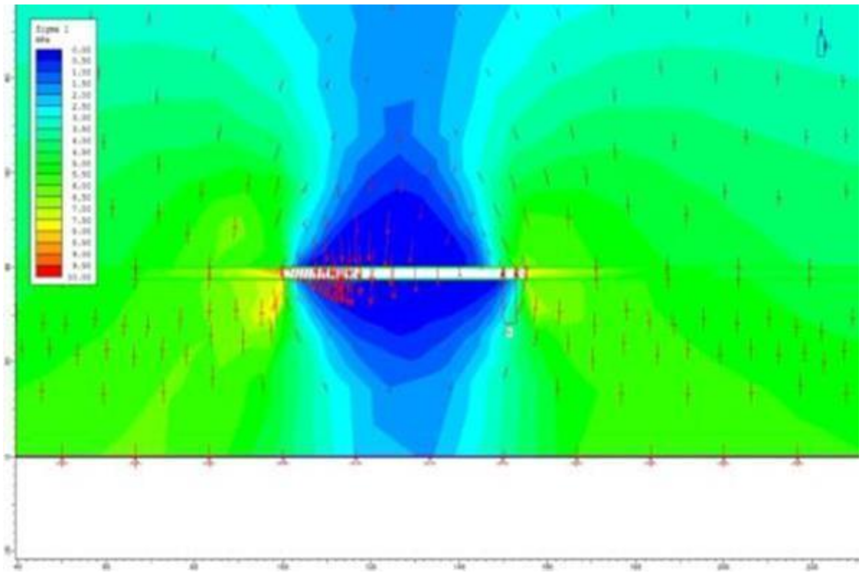

Figure 3: Implementation of designed model and movement of earth layers

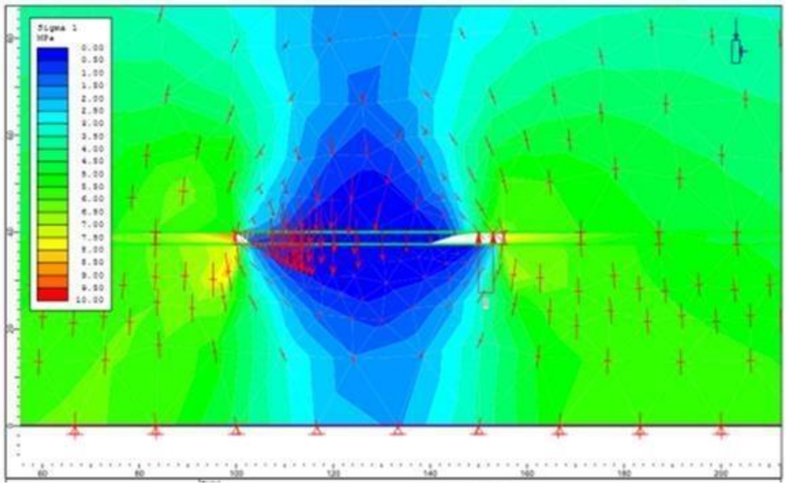

Figure 4: Roof collapse and creation of gob zone in Tabas mine working face

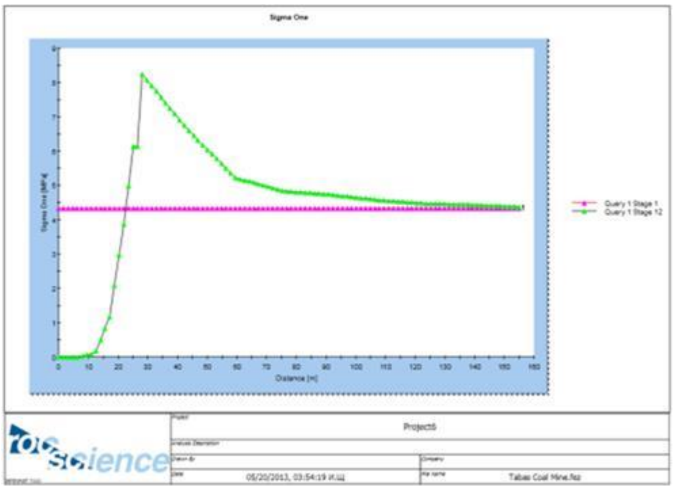

Figure 5: Stress variation curve based on distance from gob zone in longwall face of Tabas coal

CONCLUSION

The modeling study demonstrated that there will be a significant improvement in gas capture with the availability of inseam horizontal drill holes close to the working face. The effectiveness of the gas capture in the order of 10 m^3/t may occur as the by horizontal inseam holes becomes within 30 m from the coalface, due to local fractures created by these stress variations. By performing horizontal drill operation and making the required low-pressure space, this gas can be collected and utilised for economic benefit.

The greatest degree of roof stress occurs at the longwall coalface area, and hence requires special attention. The coal bed in this region is compressed and functions as an inflammatory rock mass with increasing coalface stress. This results in the formation of local fractures at the coalface, which increases the risk of sudden gas emission and possible coal and gas outburst.

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