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Goaf area exploration in Anjialing surface mine based on the C-ALS

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ABSTRACT
In order to ensure safety in production, a 3D model is established in the mining boundary of the Anjialing surface mine by using C-ALS to explore goaf. The roof height of the mined out area is consistent with the results of a 3D laser scanner that verified the model by drilling exploration. The coal seam is shallow in the Anjialing district. Small-scale coal mining has a long history. A small kiln mining area in the centre of the first mining area damaged the 4th and 9th coal seam severely. Goaf 3D laser scanning technology has been widely used at home and abroad as an advanced goaf measuring instrument. C-ALS is used for the 1302 and 1316 levels in Anjialing district to carry out goaf exploration; the results show that the volume of the goaf is 21138m^3. Through carrying out data processing and 3D modelling for the goaf, a basic idea for subsequent safety evaluation of goafs, disaster warning, and governance programs for the goaf are provided.
KEYWORDS: Goaf area; C-ALS; surface mine; 3D model

1. INTRODUCTION

The mined out area is a cavity produced by artificial digging or natural geological movement under the earth's surface. The goaf of the small kiln is an underground man-made activity site formed by previous mining behaviour. It not only includes the underground space of the well lane and resource exploitation, but also includes secondary space produced by the movement of rock strata caused by mining, as well as the space for the formation of secondary disasters after mining (Liu, 2008; Sun, 2009). The goafs formed by underground mining have a certain influence on the ground environment, and at the same time threaten the life and property safety of residents in the mining area.

Three dimensional laser scanning technology of goaf is a 3D precision detection method based on laser ranging. It can detect the goaf through scanning by stretching a rotating head which can be integrated with a laser distance measuring instrument in the inner goaf. Compared with the traditional geophysical prospecting and drilling methods, C-ALS can accurately grasp information like the three-dimensional shape, space position, the actual boundary, the area of the top floor, and the volume of the goaf (Liu, 2012; Ren et al., 2013; Xia et al., 2009). The information could be used to verify the results of geophysical prospecting and drilling in the goaf, and to guide the further development of geophysical prospecting and drilling in the mined out area of the mine.

2. CAVITY-AUTOSCANNING LASER SYSTEM（C-ALS）

MDL developed a robotic laser exploration system", that can fquickly and safely explore the working area in the mine through a hole drilled beforehand. This system is called “Cavity automatic laser scanning system”(C-ALS) (Ma et al., 2013; Ma et al.). THe C-ALS system is a kind of self-navigation, "mechanical" robot probe. It can enter into the dry waste (in use) within the working area of the mine exploration. The diameter of the device is only 50 mm, therefore it can be placed into pre drilled holes whose diameter are at least 65 mm. Using a front micro laser scanner, it measures the three-dimensional shape of the cavity and the surface reflection. C-ALS can be lowered to a depth of 300 m, and the distance between the upper and the horizontal detection is 100 m.

C-ALS has the following advantages:

(1)Prospecting dangerous underground mine areas in a safe way.

(2) 3D results available within a few minutes, no need to wait for a few days.

(3) Automatic scanning operation.

(4) Flexible use method.

(5) Small size and convenient transportation.

(6) 360 degree scanning coverage with no “blind spot”.

(7) High precision and accuracy of goaf and space measurement.

The device structure is shown in Figure 1.

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Figure 1: Equipment structure of C-ALS.

Below are the field devices and operating conditions, as shown in Figure 2.

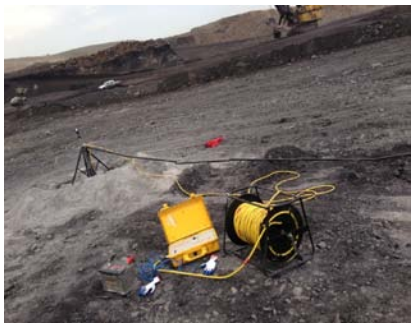

Figure 2: Three-dimensional laser scanning equipment working drawing.

3. EXPLORATION IN ANJIALING

3.1 General Situation of Anjialing Surface Mine

Anjialing surface mine is located in the south central Pingshuo mining areaConstruction began in April 1998, and the design and production capacity is 10.0 Mt/a. In 2003, it reached design production capacity when the production of Anjialing Surface Mine reached 32 million tons. The major minable seams are buried from 100 m to 200 m. From top to bottom the recoverable coal seams are No. 4, No. 9 and No. 11. They have an average thickness of 29.5 m. The present mining stope is shown in Figure 3.

Figure 3: Stope situation.

The coal seam is shallow in the Anjialing district, and small-size coal mining has a long history. A small kiln mining area distributed in the centre of the first mining area damaged the 4th and 9th coal seam severely. The destroyed area of No. 4 and No. 9 seams is 3.5 km^2 and 0.275 km^2, respectively. Additionally, the surface subsidence and cracks increase rainwater infiltration. The water in the goaf is in a dynamic process where the no-water area may gradually become a water area. As a long-term collapse area, there is probably a small amount of hydrocele.

3.2 Goaf Scanning

To grasp the characteristics of the goaf in Anjialing accurately, China Coal Research Institute has used a 3D laser scanner to scan the drillings that exposed the goaf. From June 3rd, 2013 to June 6th, 2013 and July 16th to 18th, technicians detected a goaf for the 1302 and 1316 face. In total they scanned 18 drillings and a natural collapse pit (scanned the pit 5 times). 15 of the drillings are successfully scanned while the others are failed. The pit was successfully scanned 5 times. As a result, there were a total of 20 successful scans. The results are satisfactory.

Figure 4: Anjialing three-dimensional laser scanning site.

Table 1: Probe hole information.

Sample ID	location			Result of drilling	Discover goaf or not
	East	North	Height		
1	11703.7	71356.5	1316.8	Appear	Yes
2	11712.0	71345.7	1316.6		
3	11564.1	71292.5	1302.1	Appear	Yes
4	11564.6	71292.0	1302.2		
5	11547.7	71304.0	1302.7		
6	11538.6	71303.6	1302.7		
7	11542.8	71309.3	1302.8		
8	11531.4	71304.6	1302.5	Appear	No
9	11537.6	71250.9	1302.7	Appear	No
10	11529.5	71251.2	1302.7	Appear	Yes
11	11693.2	71356.6	1316.7	Appear	Yes
12	11676.7	71359.2	1315.1	Appear	Yes
13	11648.5	71341.2	1302.4	Appear	Yes
14	11678.4	71348.7	1314.8	Appear	Yes
	11675.6	71344.3	1314.4		
	11676.4	71340.8	1314.9		
15	11687.8	71331.6	1317.8	Appear	Yes

Sample ID	location			Result of drilling	Discover goaf or not
	East	North	Height		
16	11690.0	71334.9	1317.9	Appear	Yes
17	11650.0	71317.4	1302.7	Appear	Yes
18	11648.8	71326.0	1302.6	Appear	Yes

3.3 Description of goaf

According to the recent scans, the goafs exposed by drillings are connected. Descriptions of the goaf are as follows:

(1) The roof and floor are higher in the north and lower in south, which is similar to the coal seams. As a result of the fact that the dip of the floor is increases gradually in the southward direction, the goaf is higher in the south and lower in north.

(2) In the north of the proved area, the lowest height of the roof is 15 m. In the southwest, the highest height of the goaf is 32 m. The longest axis is nearly 60 m. The vertical height is low in the north and high in the southwest. In proved area the lowest vertical height is 5 m and the highest vertical height is 15m. The width of the goaf is about 15 m.

(3) The volume of the proved area in the goaf is 21139 m^3.

(4) In the goaf, there is dust and gas of water. The temperature is low. It is judged that there is no water or fire in the goaf.

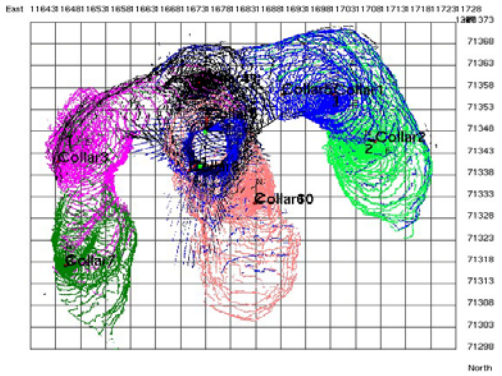

Figure 5: Anjialing goaf three-dimensional laser scanning the overall situation point cloud (Overlook).

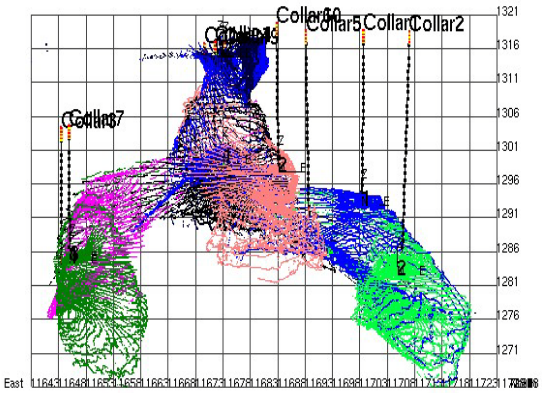

Figure 6: Anjialing goaf three-dimensional laser scanning the overall situation point cloud (Front view).

According to scanning of the caved pit, it was found that there is a goaf around the pit that is connected to the previously discussed goaf. 6 drillings, F(01) , F(02) , G(01) , G(02) , G(03) , and G(04) were drilled by technical personnel. The locations of the drillings are shown in Table 1. The drilling showed that there was a goaf around the drilled area. The height of the roof is similar to the scanned results.

4. GOAF MODELLING AND DISPOSAL

4.1 Goaf modelling

Goaf 3D modeling was performed using the Geomagic Studio software using the data from the 3D laser scans (Liu et al., 2009; Wang et al., 2010; Chen et al., 2012). The volume of the goaf was calculated at the same time. The whole goaf and volume are shown in Figure 7..

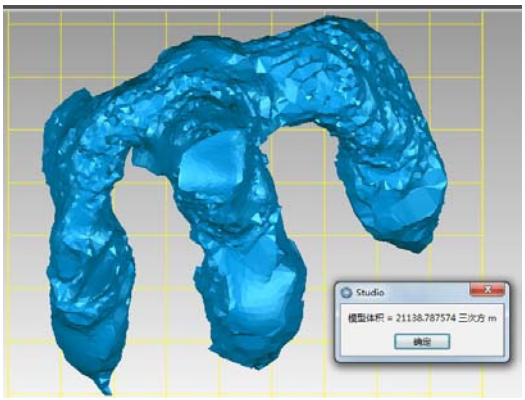

Figure 7: Anjialing goaf 3D modelling view.

Scanning results accurately determined the trend of the goaf. The distribution of goaf is in line with the basic characteristics of small coal mining. The effect is very significant, and therefore provides an accurate basis for the further processing of the goaf.

4.2 Goaf disposal

The blasting method is the most commonly used method in the production process of handling goafs in surface mining. According to the relationship between the mining area and flat bench, the loose blasting method is suggested to treat goafs. The specific practices are as follows:

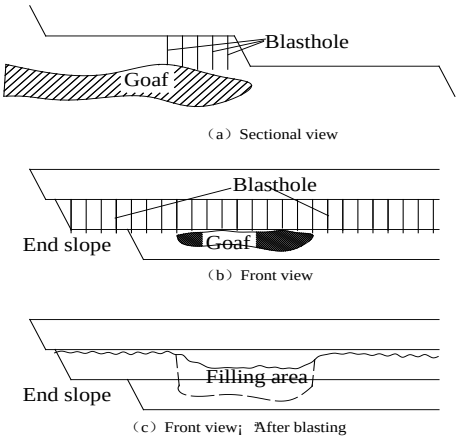

Figure 8: Loose blasting in goaf disposal.

The results of loose blasting in the goaf in Anjialing surface coal mine are as shown in Figure 9.

Figure 9: The goaf after blasting.

5. CONCLUSION

(1) There are many goafs in Anjialing surface mine. Exploring and disposing of the existing goafs has great importance to guarantee safe production in the surface mine.

(2) By using the "cavity automatic laser scanning system", the Anjialing surface mine area goafs were found. A large scale drilling scan discovered that the goafs were connected. By drilling verification, it was found that the gob roof elevation is the same as the 3D laser scanner elevation.

(3) An accurate computation of the goaf's volume was made via goaf 3D modeling. It was prove that the 3D laser scanning results give an accurate judgment of the goaf trends.

(4) Based on the goaf 3D model, the goaf was disposed of with loose blasting to lay a foundation for safe production in the surface mine.

6. REFERENCES

Chen Kai,Yang Xiaocong, Zhang Da(2012). Study on cavity 3D laser scanning deformation monitoring test. Non-ferrous Metal, Volume 64, pp. 1-5.

Liu Xiling(2008). Research for stability analysis and safety forewarning of cavity based on laser 3D detection[D]. Central South University.

Liu Jun, Wand Di(2009). Integrated Application of GPS and 3D technology in Detection of Mined-out Area. Metal Mine. suppl, pp. 512-515.

Liu Kewei(2012). Study of 3D laser scanning visualization and analysis of the stability of hazardous cavity under open-pit mine[D]. Central South University.

MA Yutao , Peng Wei(2013). Study on Cavity-Autoscanning Laser System (C-ALS) and its application in Anqing Copper Mine(Non-ferrous Metal). Volume 65, pp. 9-12.

MA Haitao, LIU Yongfeng, HU Jiaguo. Study on gob detection and visualization of three-imensional model based on C-ALS. Journal of Safety Science and Technology. Volume 6, pp. 38-41.

Ren Hongwen, Liu Zhaofu, Han Zhiyao Wang Jinghai, Deng Guoping.(2013) Application of 3D Laser Scanning Technology in the Surveying and Mapping. Gold Science and Technology. Volume 21, pp. 64-68.

Sun Shufang. Analysis and Processing of Goaf dimensional laser scan data[D]. Kunming University of science and technology,2009.

Xia Yonghua, Fang Yuanmin, Sun Hongsheng, Zuo Xiaoqing WA Xuekun Chen Jie(2009). Error Analysis and Calibration of 3D Laser Monitoring System Survey in Finished Stopes. Bulletin of Surveying and Mapping. Volume 18, pp.18-21.

Wang Guotao , Luo Zhouquan , Liu Xiaoming, Zhu Qingling(2010). Application of 3D monitoring and mines based on visual modeling cavities in metallic cavity features. The Chinese Journal of Geological Hazard and Control. Volume 21, pp. 104-109.