Hazard analysis for Jingerquan mine based on GPS monitoring technology

Ma Fengshan(1), Ding Kuo(1), Zhu Jianjun(2), Tian Maohua(2)

(1) Key Laboratory of Shale Gas and Geoengineering, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
E-mail: 309520428@qq.com
(2) Hami Jingerquan Mining Co. Ltd., Hami 839000, China

Abstract

Analysis of mining hazard is a complex engineering problem. Taking Jingerquan mine for instance. it adopted the shallow-hole shrinkage method at the previous mining stage which severely disturbed the overlying rock mass. Therefore, the filling method is used instead in the later stage. Based on the result of GPS monitoring, the surface deformation is analyzed and the deformation region is divided into three parts according to rock mass deformation mechanism and cracks process. As the mining activity continues, surface deformation region will expand. This article laid a theory basis for ensuring mining safety.

Keywords: mining engineering, hazard analysis, GPS, surface deformation

1. Introduction

Owing to the rapid development of national economy and the increasing demand for mineral resources, the mining scale of underground resources increases continuously. Due to the complexity of mining method, geological conditions, in situ stress and geological structure (Huang and Chen, 2009; Fang and Peng, 2004; Wang, 2006; Xi and Chen, 2011), surface deformation and rock mass movement caused by underground mining is a complicated engineering problem.

Jingerquan copper-nickel mine was founded in 2002 and put into production in 2005, due to the limitations of materials and funds, shallow-hole shrinkage mining method was adapted in the early mining stage. Affected by violent mining procedures, the integrity of overlying rock mass integrity was destroyed, a large area collapsed and a wide range of surface cracked (Deng and Li, 2001). As a result, the filling method was chosen instead of shallow-hole shrinkage mining method in 2010. The filling method can effectively reduce the surrounding rock movement and protect the surface integrity (Wang and Gao, 2003). While because of the overlying rock mass stability is low, the surface deformation is still in further development (Li and Lu, 2006; Sun and Jiang, 2008; He and Yan, 2000).

In this paper, based on field survey results and monitoring data, the surface deformation characteristics of Jingerquan mine was analyzed and the deformation region was divided into three parts according to the mechanism of rock mass deformation and the process of cracking, and the hazard of the area was also studied.

2. Geological condition and mining situation

Jingerquan mine is located in the south of the Central Asian orogenic belt, Regional tectonic line direction is NNE, 32 faults are mapped, most of which are high angle reverse faults. Many fractures develop in the mining area, and the main fracture lies in the central part of the mining area. Its strike angle is NEE, dip direction is SSE and inclined to 80° -85°. Constantly affected by late tectonic activity, foliated and mylonitic structures and other weak structural planes developed in the contact zone between the ore and rock, There's a large difference between the lithology of both side, the south side outcrops gabbro, monzonitic granite and metamorphic rocks in carboniferous strata and the north side outcrops gabbro, diorite, mirror spring basic - ultrabasic rock.

Jingerquan mine was put into production in 2005 and delimit the mining depth for 1362 m to 840 m elevation. According to the distribution location orebody can be divided into two parts (Fig.1). Shallow-hole shrinkage mining method was used amidst the 1090 m and 1047 m and 989 m middle sections. Since ground pressure control and management is difficult in mining and the fissures spread widely to the surface, as a result, the rock above mined-out areas were turned into granular structure. So the filling method was chosen instead of shallow-hole shrinkage mining method in 2010 through 965 m and 925 m middle areas.

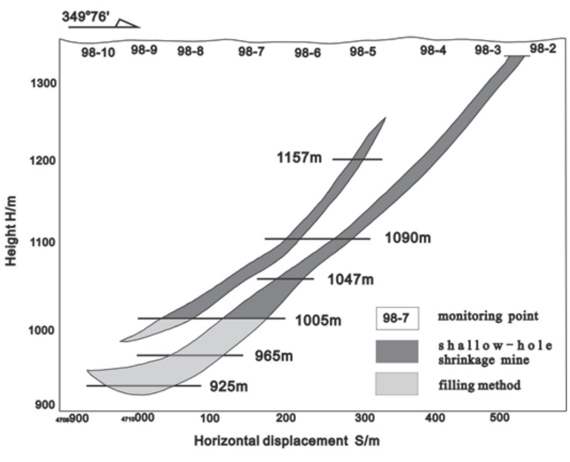

Fig. 1 Mining method

3. Monitoring data

3.1 Ground subsidence

Ground subsidence can be seen since the field survey and ground surface monitoring for the first time in 2013, surface subsidence have been extended to the outside along with the mining activities. Outside the area of ground subsidence, ground surface deformation evolves into gradual type.

3.2 Surface cracks

A total of 12 surface cracks in mine and two crack zones constituted of the north crack zones and the south crack zones are observed. The sedimentation basin boundary divided by 20 mm a year is shown in Figure 2.

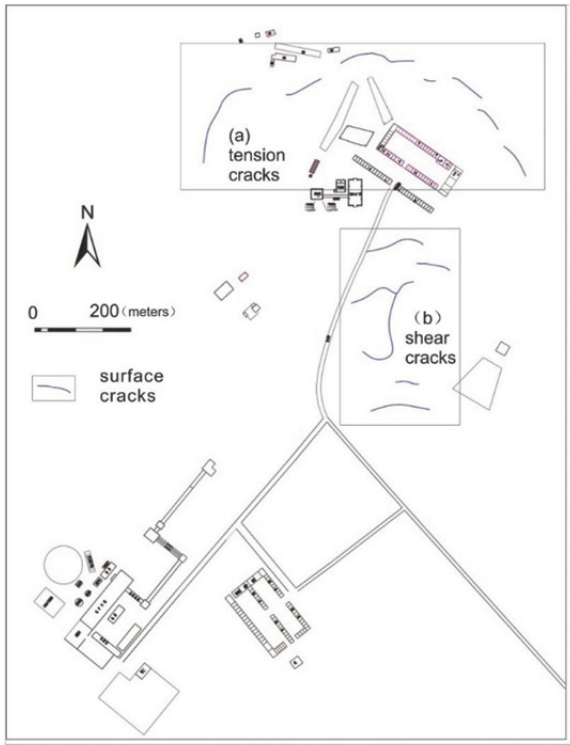

Fig. 2 Location of Surface cracks

The north crack zone mainly comprises tensile cracks and exposed on the northern edge of the surface subsidence basin. The development of the north crack zone is parallel to the edge of subsidence basin. It is composed of seven fractures with good extensibility. The total length is about 400 m. The crack belt get a characteristic of intermittent development and has a tendency to breakthrough. The south of Surface subsidence basin edge has not yet found that the tensile fracture.

Fig. 3 Tension cracks

The south crack zone is shear cracks and exposed inside the surface subsidence basin edge. It is composed of six cracks. The crack zone get a characteristic of soil extrusion bulge and arch which the height is about 5mm, Besides, X cracks exposed near the subsidence center and arranged pinnate right-handed.

Fig. 4 Shear cracks

3.3 Surface deformation

The mine was monitored for four times a year from July 2013 to April 2015 with GPS monitoring method, There are eight monitoring lines(No.94-No.101) and 101 monitoring points in total. They cover all the subsidence and deformation area in the mine.

Displacement vector diagram and displacement contour map is shown in Figure 5.

From the above monitoring results, the surface deformation area is similar to an irregular round, there is only one subsidence center and the direction of regional deformation points to the subsidence center. Maximum vertical displacement is 629.09 mm, It shows that there is a strong deformation near the subsidence center. The vertical displacement of monitoring points is shown in Table 1. The area whose vertical displacement is larger than 50 mm accounts for 10.40% of the total mining area, located at the center of the mining subsidence within 70 meters. And vertical displacement is less than 10 mm accounts for 72.69% of the total area, the subsidence area is relatively concentrated and the rest of the region as a whole remained stable.

Table 1 Percent of vertical displacement from July 2013 to April .2015

Vertical displacement	<[-10] mm	[-100]-[-50] mm	[-50]-[-30] mm	[-30]-[-10] mm	[-10]-[0] mm	[0]-[20] mm
Percent	6.08%	4.32%	6.43%	10.48%	49.68%	23.01%

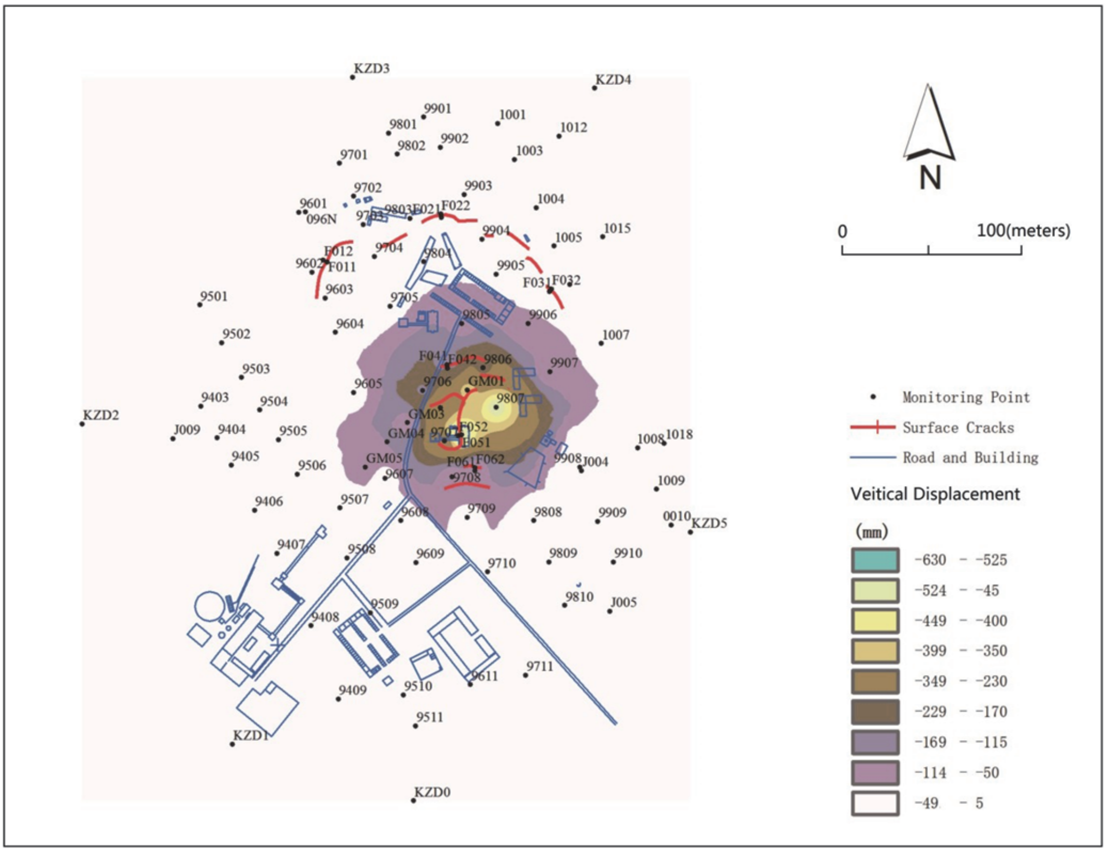

Fig. 5 Contour of superficial vertical displacement

4. Analysis of surface hazard

Combining with the feature of surface deformation, the mechanism of rock mass deformation and the process of cracks, the surface deformation zone is divided into three areas: fracture zone, deformation zone and the stable zone (Fig.6). We will describe the mechanism and deformation characteristics of the three zones respectively.

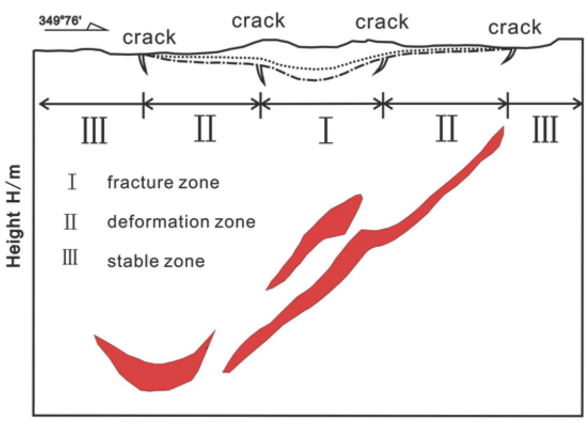

Fig. 6 Surface deformation area

4.1 fracture zone

There is no limit to the lateral stress around the vertical tubular damage area, therefore, the surface deformation and fractures will develop at a rapid speed until mining stop. The area is named fracture zone.

The accumulative deformation of surface is originally stable, and then entered a rapid deformation stage, the curve of the accumulation deformation with time in the zone is polyline, slow after the first steep, its representative points for F042 and F052.

The surface cracks in fracture zone is on a large scale and the maximum crack have a width of 40 cm. The cracks are in the stage of slow growth and have small hysteresis relative to the mining.

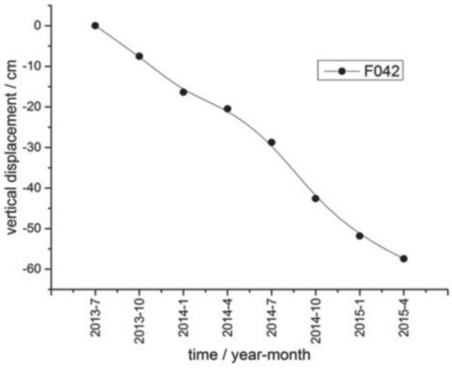

Fig. 7 Horizontal displacement of F042

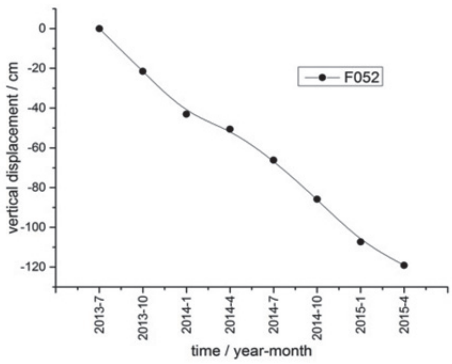

Fig. 8 Horizontal displacement of F052

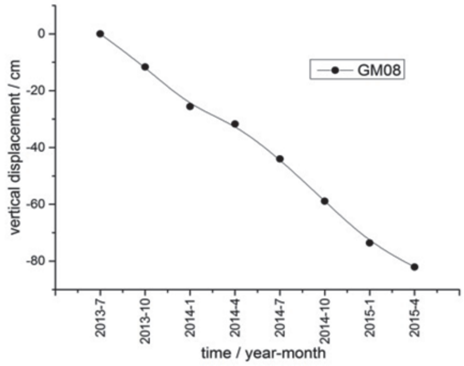

Fig. 9 Horizontal displacement of GM08

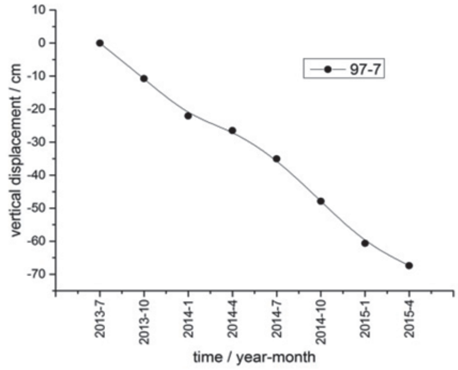

Fig. 10 Horizontal displacement of 97-7

4.2 deformation zone

With the increase of the distance of the vertical tubular area, the lateral stress increase while just bending deformation occurs. This area is known as the deformation zone.

Accumulative deformation to the surface is given priority to with stable deformation and the curve of the accumulation deformation with time in the zone is linear. Its representative points for GM08 and 97-7.

The size of surface cracks in deformation zone is still large but much smaller than that in fracture zone, the width of cracks ranges between 0.5 ~ 3.0 cm. The cracks in the deformation zone have a more apparent hysteresis relative to the mining than fracture zone.

4.3 stable zone

In the whole deformation area, the stable zone has the farthest distance to the vertical tubular area, the lateral stress is close to the original ground stress.

The region located at the outer edge of the ground surface caused by the mining, its cumulative deformation is small and the error in the process is bigger than the accumulative deformation value, as a result, the curve of the accumulation deformation with time in the zone is fluctuate. Its representative points for 94-9 and 95-4. There is no crack in this area.

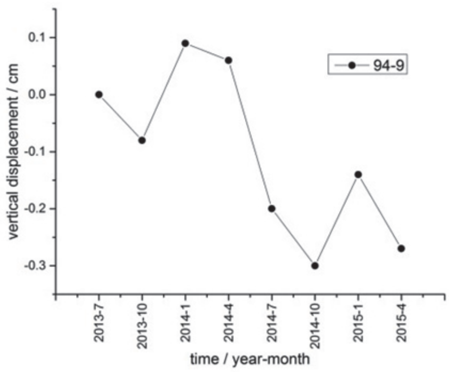

Fig. 11 Horizontal displacement of 94-9

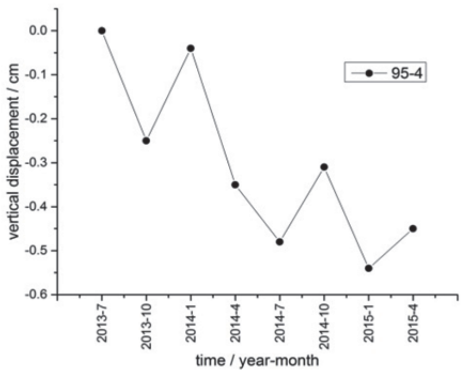

Fig. 12 Horizontal displacement of 95-4

5. Result and discussion

Because of the considerable development of mining structure and broken rock mass, the stability problems of the engineering rock mass get serious. According to the analysis of vector and displacement, filling method cannot completely avoid the surface of a wide range of ground fissure. Since the shallow-hole shrinkage mining method has greatly weaken the integrity and stability of the overlying rock mass, a wide range of surface subsidence and ground fissures still happened.

In our research, the surface deformation caused by underground mining is analyzed and further deformation mechanism of underground mining is described, we divided the surface deformation zone into three areas: fracture zone, deformation zone and the stable zone. As mining activities continues, the surface deformation is still in development, so their development trend and influence on the surface structures need to be further investigated.

Acknowledgments

The study was sponsored by the National Natural Science Foundation of China (Grant Nos. 41372323, 41172271) and was a science and technology support project of the Xinjiang production and construction corps (Grant No. 2014AB034). Grateful appreciation is expressed for this support.

Reference

DENG Jian, LI Xi-bing, GU De-sheng (2001): Ground pressure and control techniques in non-pillar continuous mining method [J]. The Chinese Journal of Nonferrous Metal, Vol. 11, No. 4, pp. 666-670.

FANG Jian-qin, PENG Zhen-bin, YAN Rong-gui (2004): The law of tectonic stress mining ground surface subsidence and its engineering treatment method [J]. Journal of Central South University of Technology (Natural Science), Vol. 35, No. 3, pp. 506-510.

HE Yue-guang, YAN Rong-gui, ZENG Zhuo-qiao (2000): Law of mining surface movement by the effect of tectonic stress [J]. Mining and Metallurgical Engineering, Vol. 20, No. 3, pp.12-14.

LI Xiao, LU Shi-bao, LIAO Qiu-lin, DU Guo-dong (2006): Distribution characteristics and field monitoring of ground fissures caused by backfill mining [J]. Chinese Journal of Rock Mechanics and Engineering, Vol.25, No. 7, pp.1361-1369.

Sun Xiu-bo, Jiang Yong-zhen, Liu Mao-hua, Zhu Guang-shan (2008): Characteristics of ground fissures and the formation mechanism is analyzed in FuShun, The Chinese Journal of Geological Hazard and Control, Vol.19, No. 4 , pp.42-45.

Wang Jian(2006): Study on Ground Subsidence Law of East District in Chengchao Iron Mine and Displacement Mechansim of Main East Shaft, Metal Mine, Vol. 358, pp. 7-11.

WANG Zheng-hui, GAO Qian(2003): Study on mechanism and stability of filling in stoping cemented fill method [J]. Metal Mine, Vol. 328, No. 10 , pp. 18-20.

XI Ren-shuang, CHEN Cong-xin(2011): Study of influence of discontinuities on rock movement and surface deformation in eastern area of Chengchao iron mine [J]. Rock and Soil Mechanics, Vol. 32, No.2, pp. 532-537.