Novel solution of GNSS and Insar system for fully automated mine monitoring

Key words: Monitoring; Mine; GNSS; Insar;

SUMMARY : Mine monitoring solutions are widely used in many different types of mines. Traditionally, we use total station as the main sensor to monitor it because its reliability and cost. In this paper, we would like to present a cost effective and high accuracy solution, which use full constellation full band GNSS receivers or use the latest insar systems instead of traditional total station monitoring. Based on full constellation full-band GNSS receivers with high computing power edge computing function. Eventually realize high precision positioning.

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1. INTRODUCTION

Mining is generally carried out either by opencast or underground mining. Underground mining involves the formation of underground mining tunnels (shafts, inclined shafts, shafts, flat tunnels, cross tunnels, slope tunnels, etc.) and underground extraction areas. The waste from mining utilisation is usually deposited in the form of tailings ponds (wet drainage method) or drainage dumps (dry drainage method). Therefore, in this article, the monitoring techniques of GNSS and Insar systems are mostly applied to open pit mine monitoring and tailings pond monitoring.

Open pit mine slope engineering is a large rock project formed by using rock as engineering material and engineering structure and mining operation as construction means. As the depth of open pit mining increases, the height of the slope increases, gradually forming a high and steep open pit slope, making extraction production and slope maintenance increasingly difficult. A large proportion of mines at home and abroad are opencast. In China, for example, iron ore accounts for 85% of the metal mines, non-ferrous metal mines account for 45%, chemical mines account for 70%, and construction materials are all mined in the open pit. As shallow mineral resources continue to be exploited and gradually depleted, deep concave open pit mines will become the development trend for open pit mines. The maximum height of open pit slopes is already over 1,000 metres. During deep concave mining, the height and angle of the side slopes gradually increase as the mining depth increases. With the continuous formation and development of high and steep slopes, the safety and stability of the slopes are getting worse and worse. On the other hand, increasing the slope angle is an important means to fully recover mineral resources, reduce stripping production costs and increase economic benefits in open pit mines. Therefore, the contradiction between ensuring the safety of the slope and increasing the economic efficiency in the process of deep mining in open pit mines is becoming increasingly prominent.

The main technical parameters for the safe operation of tailings ponds, such as dam deformation and displacement, reservoir water level and depth of infiltration line, are regularly monitored manually on site using traditional instruments. The workload of safety monitoring is high and is influenced by many factors such as weather, labour and site conditions, and is subject to systematic and manual errors. Manual monitoring does not allow for timely monitoring of the technical parameters of the tailings ponds. It is difficult to keep track of the technical safety indicators of the tailings ponds in a timely manner and does not allow for real-time early warning throughout the day, which is a major safety hazard. At the same time, the collation and analysis of data often lags behind the production operation, which will affect the safety production and safety management level of tailings ponds. The application of GNSS technology to tailings pond monitoring makes it possible to achieve both full automation and 24/7 monitoring requirements.

2. OBJECTIVES OF MINE MONITORING AND CONTENT OF MONITORING ITEMS

2.1 Open pit mine

Open pit mining is generally carried out using either the lateral one-sided cut method or the top-down four-week method.The lateral one-sided method, also known as the lateral cut-in hillside method, is suitable for above-ground deposits with a small vein or face distribution, and does not require high workings and production capacity. The capacity is usually greater. It is suitable for large underground deposits.

The slopes formed after excavation in open pit mines are usually rocky slopes where large volumes of rock are as a result of the stripping of large volumes of rock, the stress balance of the original rock is disrupted and the residual slope is relieved and tends to rebalance. During the process of re-equilibration, the slope is subject to stress deformation, which may result in rock fracture, crumbling, and possible slope instability resulting in collapse or landslide.

A typical mine side slope is shown as following

Typical high and steep sided open pit mines:

Name	Height/m
Bingham Canyon Copper Mine, Salt Lake City, USA	970
Fermiston Open Pit Mine, Australia	900
Zijinshan Gold and Copper Mine, Zijin Mining Group Co.	880

Taiyuan Iron and Steel Jianshan Iron Ore Mine	772
Tibet Yulong Copper Company Limited Phase II Project Side Slope	715
Jiangxi Copper Dexing Copper Mine	710
Shougang Mining Company Shuizhan Iron Ore Mine	660
Taihe iron ore mine of Chongyang Group	618
Udachnaya Diamond Open Pit, Russia	600
TISCO Ekou Iron Ore Mine	570
Russia Minry (Mir Diamond Mine) open pit	525
Shougang Dashihe Iron Ore Mine	516
Yunfu Sulphur Iron Ore Enterprise Group Company	504
Hainan Mining United Co.	497
Baotou Iron & Steel Baiyun Ebo Iron Ore Mine	480
Jiangxi Copper Industry Yongping Copper Mine	470
Jinduicheng Molybdenum Industry Group Co.	453
Wuhan Iron and Steel Group Mining Company Daye Iron Mine	432

The classification of mine slopes is as follows.

1. Ultra-high slope: $H > 500m$
2. High slope: $300m < H \leqslant 500m$
3、Medium slope: $100m < H \leqslant 300m$
4、Low slope: $H \leqslant 100m$

2.2 Tailings ponds

A tailings pond is a place where tailings or other industrial wastes from metal or non-metal mines are stored in a dam to intercept a valley or fenced area. A tailings pond is a high potential energy source of man-made debris flow hazards that can easily cause serious accidents in the event of a dam failure.

1、The most common forms of tailings storage arrangements are: valley type, hillside type and flatland type.
2. Tailings ponds usually consist of the following facilities: stockpile system (consisting of initial dams, later dams, discharge pipes, etc.), flood drainage system (generally including interceptor ditches, spillways, drainage wells, drainage pipes, drainage tunnels and other structures), return water system (most use the drainage wells and pipes in the pond to bring clarified water to the downstream return pump station and then lift it to the high level pond; some also have movable pump stations at the edge of the water surface in the pond to directly extract (clarified water is lifted to the high level pond).
3. Safety classification of tailings ponds: The safety of tailings ponds is mainly classified according to their flood control capacity and the stability of the tailings dams, which are usually classified as dangerous, hazardous, sick or normal.
4. The core structure involved in the safety of a tailings pond is the tailings dam. Tailings dams are generally constructed using the upstream, downstream and midline methods.

3. AUTOMATED MINE MONITORING SOLUTION

3.1 Open pit mine

Mine slopes mainly require monitoring of slope ground stress, relative sliding surface displacement, relative slope deformation (cracks, tilts, etc.), slope water environment and slope and surrounding vibrations, and earthquake monitoring in seismic areas. The main items of mine slope monitoring are as follows:

NO.	Category	content	Description
1	Mechanical	Rock Stress	Strain gauges
		Anchor tension	Strain gauges
		Anchor cable tension	Dynamometers
2	Deformation	Surface displacement	GNSS
		Surface cracks	Fractometer
		Deep displacement	This item is
		Rock deformation	Multi-point
		Rock face dip	Inclinometer
3	Seepage	Seepage pressure in the surrounding rock	Seepage pressure meter
		Slope water content	Optional for soil
		Slope infiltration	Optional for soil
4	Environmental	rainfall in the mining area	Rain gauges
		blast vibration	Mass
		Slope microseismic	Microseismogra
		Seismic monitoring	Seismographs

The selection of equipment should meet the requirements of the relevant national regulations and specifications, and at the same time meet the actual monitoring needs of the project. Specific selection is as follows.

(1) Absolute surface displacement monitoring: GNSS displacement meter is selected, with

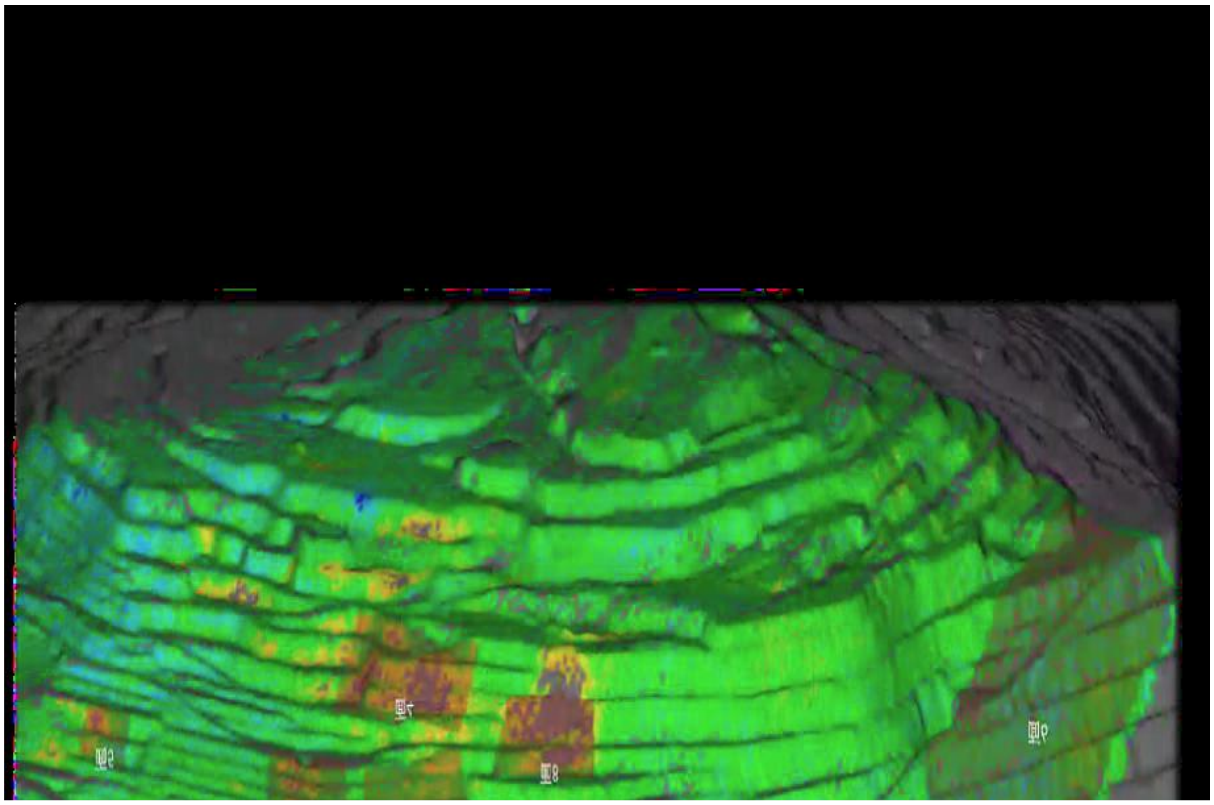
accuracy better than 2.5mm for plane and 5mm for elevation.
(1) Absolute surface displacement monitoring: GNSS displacement meter is selected, with an accuracy better than 2.5mm for plane and 5mm for elevation.
(2) Relative displacement monitoring on the surface: use a wire displacement meter (fissure meter) with an accuracy better than 1mm or 0.5mm for soil monitoring and 0.2mm for rock monitoring.
(3) Deep relative displacement monitoring: use fixed inclinometers with an accuracy better than 0.02° and a range of not less than 15°.
(4) Monitoring of settlement in deep parts: electromagnetic type settlement meter with an accuracy better than 2mm is used.
(5) Surface tilt and deformation monitoring: use inclinometers with an accuracy of better than 0.01° and a range of not less than 30°.

InSAR monitoring system

The radar is used to transmit microwaves to the target area and then receive the reflected echoes from the target to obtain SAR complex image pairs for imaging the same target area. If there is a coherence condition between the complex image pairs, the SAR complex image pairs can be conjugately multiplied to obtain an interferogram, and based on the phase value of the interferogram, the difference in the distance travelled by the microwaves in the two imaging sessions can be derived to calculate the topography, landform and small changes in the surface of the target area.
The deformation monitoring radar is capable of monitoring a large area and the radar acquires the displacement component in the direction of the radar line of sight.

Rail-based slope deformation monitoring radar

1) Small size and light weight, easy to transport and set up
2) Built-in vibration measurement module, which can effectively reject external disturbances such as external vibration
3) 4km radius of action to meet basic requirements and monitoring accuracy in line with other products



3.2 Tailings ponds

The main items of tailings pond monitoring:

NO	Category	content	Description
1	Mechanical	Initial dam earth	Top of the centreline method
2	Deformation	Surface	GNSS
		Surface	Static level
		Deep	Fixed inclinometer
		Deep Settlement	Multi-point sinker
		Surface cracks	Fractometer
		Surface dip	Inclinometers
		Dam infiltration	Water Level Meters

3	Seepage	Dam seepage	Seepage pressure gauges
4	Environmental	Mine rainfall	Rain gauges
		reservoir water	Water level meters
		Slope	Microseismometers
		seismic	Options available
5	Other	Beach top	GNSS
		Dry beach slope	Ultrasonic Level Meters
		Water quality and	
		Video monitoring	Multi-site video surveillance

The selection of equipment should meet the requirements of the relevant national regulations and specifications, and at the same time meet the actual monitoring needs of the project. Specific selection is as follows.

(1) Absolute surface displacement monitoring: GNSS displacement meter is selected, with accuracy better than 2.5mm for plane and 5mm for elevation.

(2) Relative displacement monitoring on the surface: use a wire displacement meter (fissure meter) with an accuracy better than 1mm or 0.5mm for soil monitoring and 0.2mm for rock monitoring.

(3) Deep relative displacement monitoring: use fixed inclinometers with an accuracy better than 0.02° and a range of not less than 15°.

(4) Monitoring of settlement in deep parts: electromagnetic type settlement meter is used, with an accuracy better than 2mm, i.e.

4. CONCLUSION

Intelligent online safety monitoring is a necessary and effective scientific tool to prevent and reduce mine disaster losses. It can greatly reduce the risk of hidden hazards associated with various mine hazards and provide effective safety protection for life.

The implementation of safety monitoring systems for mine slopes, mine openings, tailings ponds and drainage dumps is an urgent priority for the relevant management and production and operation units.

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