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Research on Prediction and Monitoring Technology of Surface Deformation of Coal Mine Goaf Site

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Abstract

China is a country with large coal resources. With the large-scale mining of coal resources, more cavities and cavities are left behind, referred to as goaf site. As a large number of engineering constructions need to cross the coal goaf, monitoring and prediction of the surface deformation of the goaf site becomes extremely important. Starting from the introduction of the study on the laws and mechanisms of the surface movement of the goaf at home and abroad, this article describes several prediction models for the surface deformation of the goaf site, and lists several prediction methods for the surface deformation. Then three kinds of goaf monitoring technologies are introduced, namely conventional monitoring technology, three-dimensional laser scanning measurement technology and radar monitoring technology. With the continuous development of science and technology, the monitoring of goafs is also developing towards automation, precision and comprehensiveness.

Keywords

Goaf Site; Surface Deformation; Monitoring Technology.

1. Introduction

The goaf site refers to the area and range where the surrounding rock in the underground mining space is instability caused by displacement, cracking, breaking and collapse, until the overlying rock layer sinks and bends and causes the surface deformation and damage.[1] The movement and deformation of the goaf site caused by underground coal mining is a very complicated four-dimensional space-time evolution process. [2-4] The current method for solving the movement and deformation of the goaf site is the probability integration method, but this method can only obtain the final settlement of the site, and cannot obtain the specific settlement and deformation at a certain moment to guide the construction of the goaf site. A large number of engineering cases show that not all goaf sites can be used as engineering construction sites. Engineering construction on old goaf sites is risky, and additional deformation and residual deformation of the foundation need to be considered. This is particularly important for the research on the deformation of the ground foundation of the goaf, especially with the establishment of ecological civilization construction and the national strategy of ecological protection and high-quality development of the Yellow River Basin, higher requirements have been put forward for the ecological management of the goaf. [5-7] How to evaluate and ensure the long-term stability of the buildings (structures) on the goaf site under the additional load is a major problem currently facing.

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2. Research on the Law and Mechanism of Ground Surface Movement in the Goaf Site

Foreign scholars have done a lot of research on the subsidence of the goaf caused by the "three under one up" coal mining. Numerous studies have shown that although the goaf has undergone natural settlement for many years, it seems that the goaf has stabilized on the surface, but it is caused by coal mining. The overlying rock is broken and fractured and is not completely compacted, and there is still surface deformation. RE and RW [8] through their research on the Pittsburgh mining area, found that the mining area after room and pillar mining, the goaf site formed later will be within 50 years or longer after the end of the mining work. Movement and deformation of the ground will always occur within. Jones et al. [9] analyzed the impact of mined-out subsidence on highways in the 1970s through previous experience and data summarized. Jones [10], Sergeant [11], M. C. Wang, etc. [12] studied the hazards of mining and underlying caverns to the foundation of buildings. PalchikV [13] studied the relationship between the collapse of the old room and pillar mining subsidence area and the nature of the overlying rock, and believed that the subsidence of the abandoned mining subsidence area was related to the thickness and nature of the overlying rock, and gave the empirical relationship between the subsidence of the abandoned mining subsidence area and the thick rock layer. Eric. C. Drum [14] used two-dimensional plane stress analysis to study the mechanism of tensile damage caused by mining subsidence and summarized the technology to alleviate such damage.

A lot of research has been done in China on the law and mechanism of surface movement in the goaf site. After coal mining, the movement and deformation of the overlying strata and the surface generally go through three stages. They are the initial period, the active period, the declining period, and the Relatively stable period. [16] From the perspective of the ground subsidence curve, it basically presents a normal distribution pattern. Therefore, the probability integration method is used to predict the deformation of the ground surface [17]. The outer boundary of the subsidence basin range for mining underneath is generally elliptical [18] Under the condition of gentle mining and full mining, the fully developed surface mobile basin can be divided into three areas: the middle zone, the inner marginal zone and the outer marginal zone.

3. Prediction Method for Surface Deformation of Goaf Site

3.1 Evaluation Index of Surface Deformation of Goaf Site

For engineering construction on the mine goaf site, the first thing that must be solved is the control problem of the foundation deformation of the building (structure) on the goaf site. China is currently in a period of rapid development of engineering construction, and the problem of controlling the deformation of the foundations of buildings (structures) on the goaf site has become increasingly prominent. How to evaluate and ensure the long-term stability of the buildings (structures) on the goaf site under the additional load is a problem that needs to be solved urgently. In general sites (non-goaf sites), we usually study the vertical deformation of buildings (structures), that is, the settlement of buildings (structures), generally using settlement, differential settlement, inclination, local inclination, etc. Index value to characterize the foundation deformation of the building (structure). On the goaf site, the foundation deformation of buildings (structures) is generally characterized by index values such as settlement, inclination, curvature, horizontal movement, horizontal deformation, distortion, and shear deformation.

3.2 Prediction Model for Surface Deformation of Goaf Site

Due to the wide range of space and long time involved in surface subsidence, the structure, structure and mechanical properties of the overlying rock layer are very complicated. The current rock mechanics and mine pressure control theory cannot fully explain the mechanism of mining subsidence and the mechanism of mining subsidence. Scientific predictions [18] Therefore, the current mining subsidence prediction is mainly based on mathematics based on measured data. The time function model used to predict the surface movement and deformation of the goaf site mainly includes the

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exponential curve model (Knothe time function model and modified Knothe time function model), Hyperbolic model, Gompertz curve model, Logistic curve model, MMF model, Weibull curve function model, normal distribution function model. These models predict the settlement of a certain point in the goaf at any time, and combine it with the probability integration method. The difference between the two is the remaining deformation of the goaf at any time.

4. Monitoring Technology of Goaf Deformation

4.1 Conventional Goaf Monitoring Technology

At this stage, the most commonly used technology in the deformation monitoring of mine goafs is to directly monitor the surface deformation with measuring instruments such as deformation meters, inclinometers, and settlement meters, and to arrange ground observation stations within the mining area of the mine. Due to the continuous development of GPS technology, the technology has been widely used in mine goaf deformation monitoring, which can achieve high-precision, all-weather, simultaneous and high-efficiency monitoring of mine goaf deformation [19].

4.1.1 Advantages

Conventional measuring instruments are used to monitor the deformation of the goaf of the mine. The optical instruments are easy to carry, have high measurement accuracy, and have low requirements on the external environment. They can be used in different mining areas or different measurement environments.

4.1.2 Disadvantages

The main disadvantage is that it takes a long time to perform measurements in the field, and the later measurement data processing workload is large. At the same time, the manual measurement method is difficult to achieve continuous and real-time monitoring of the deformation of the goaf of the mine, which is not conducive to the prediction and forecast of the deformation of the subsequent goaf of the mine. In addition, due to the low spatial resolution of GPS measurement, the need for high spatial resolution monitoring of the goaf cannot be achieved.

4.2 Three-Dimensional Laser Scanning Measurement Technology

Using conventional level and total station, manual monitoring of goaf deformation is required, and the degree of automation is low. The development of 3D laser scanning measurement technology has solved this problem well. Three-dimensional laser scanning measurement is to use a laser scanner to perform non-contact scanning of the area to be measured to obtain a three-dimensional point cloud that characterizes the surface characteristics of the measurement area. By comparing the monitoring data obtained in different periods, the deformation of the goaf can be obtained. [20].

4.3 Radar Monitoring Technology

Compared with the conventional GPS, total station, etc., radar measurement technology is less affected by the external environment during use, and can obtain monitoring data in real time. At the same time, the image obtained by measurement has a higher resolution and can be applied to ground deformation monitoring.

4.3.1 In SAR Technology and D-in SAR Technology

In SAR (Synthetic Radar Interferometric Technology) technology uses the radar system carried by aircraft or space satellites, according to the position relationship between the measurement target and the radar measurement antenna, through the sensor height, beam viewing direction, radar wavelength, and the relationship between the antenna and the baseline. The acquired monitoring data image is processed, and the deformation and three-dimensional information of the monitoring target are obtained through the phase information contained in the SAR image. D-In SAR (Differential Interferometric Technology) is developed on In SAR technology, and the measurement accuracy can reach mm level. The specific data processing flow of D-In SAR technology is shown in Figure 1.

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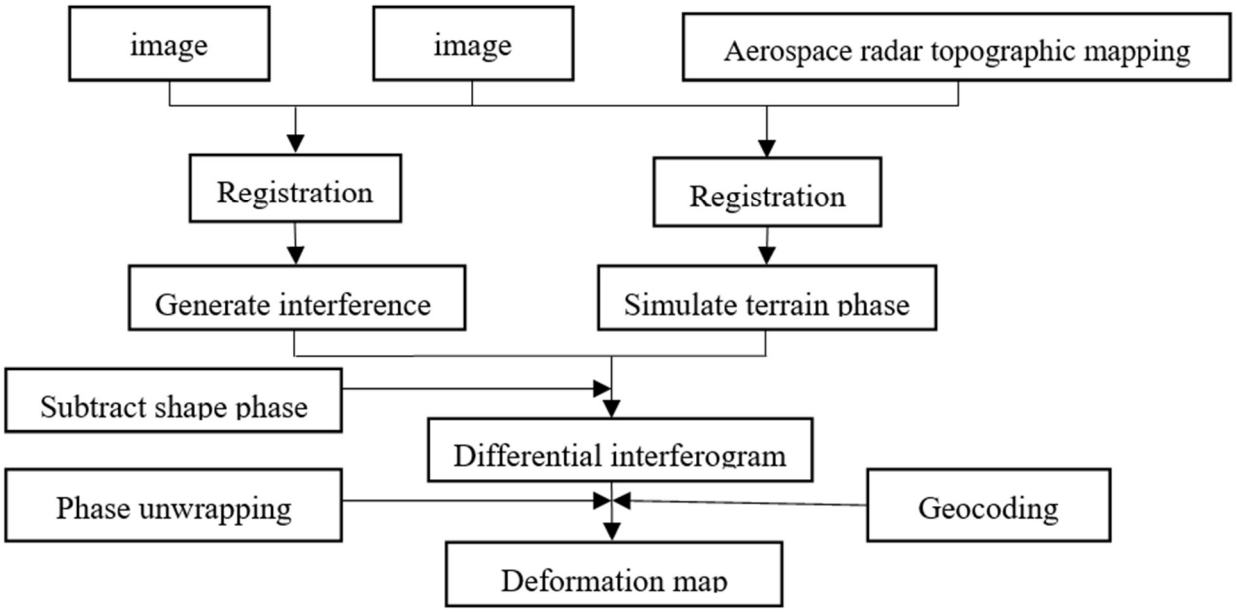

Figure 1. Data processing flow of D-In SAR technology

4.3.2 D-In SAR Integrated GPS Technology

GPS and D-In SAR measurement have their own advantages in terms of time resolution and spatial resolution. Compared with GPS, In SAR is more sensitive to elevation information, and the measurement accuracy is sub-centimeter level, but the time resolution is lower, while GPS time The resolution can reach more than ten milliseconds. Combining the two technologies can give full play to their respective advantages and achieve high accuracy in the deformation monitoring of the goaf site [21]. The technical schematic diagram is shown in Figure 2.

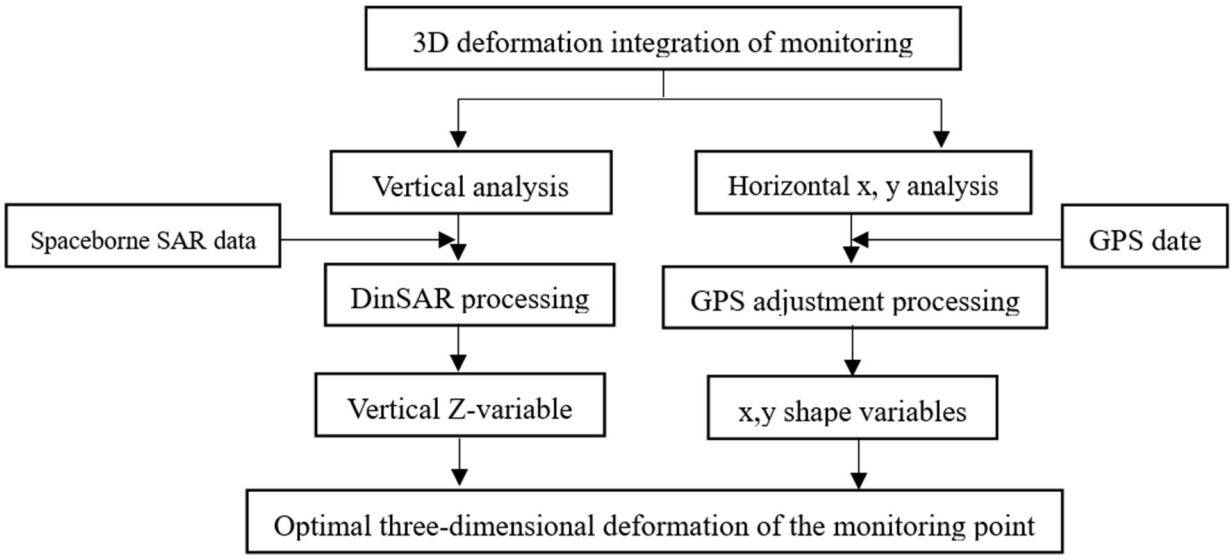

Figure 2. GPS/D-In SAR technology integration principle

5. Summary and Prospect

5.1 Summary

As a large country of coal resources and utilization, a large number of mined out areas will be left while mining resources, With the continuous advancement of national urbanization and the

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continuous development of high-speed railway, there will be more and more engineering construction on the goaf site, Subsequently, the requirements for prediction and monitoring of goaf site foundation become higher and higher, and become more and more important. Review the development of deformation monitoring technology, slowly develop to automation, accuracy and comprehensiveness, and conduct multi-directional monitoring with more advanced technology and accurate instruments.

5.2 Outlook

1) With the rapid development of satellite and radar technology, it is possible to monitor some areas limited by terrain and environmental conditions for the engineering construction of goaf sites.

2) The development of monitoring technology promotes the acquisition of monitoring data, and the obtained surface deformation data can also be used to verify the accuracy of the prediction model.

6. Conclusion

Today, with the rapid development of computer technology, radio communication technology, space technology and earth science, various technologies have entered the stage of integration and integration from independent development. Especially in large-scale disaster monitoring, a three-dimensional monitoring network with complementary advantages of various monitoring technologies has been formed from heaven to ground and from surface to point. The development of goaf deformation monitoring will be reflected in the high precision and automation of data acquisition and the specialization and informatization of deformation data analysis, so as to promote the engineering construction of goaf site and ensure the safety of engineering construction.

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