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Research in Optical Fiber Sensing Technology Fire Based on Goaf of Lao-Shidan Mine

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Abstract. In order to prevent the spontaneous combustion of the coal in the goaf of the 16401 working space of the Lao-Shidan coalmine, the optical flow sensing system, the oxygen concentration distribution and the temperature distribution of the goaf are detected in real time by using the optical fiber sensing system pre-buried in the channel. According to the preset mathematical model of CFD software, the velocity field cloud map, O₂ concentration field cloud map and temperature field cloud map are constructed, and the consistency between the calculated value and the measured ones is established by the model to determine the accurate range of the “three belts” in the goaf of 16401 working space. The distance from 0 to 54m is the heat dissipation zone, 54m~88m is the oxidizing spontaneous combustion zone, and the suffocation zone is more than 88m. The measured data provides a solid theoretical basis for the feasibility of fire prevention measures in the goaf of the 16401 working space in the Lao-Shidan coalmine.

1. Introduction

The method of coal spontaneous combustion temperature detection is an effective detection method that can directly reflect the temperature field distribution in the coal seam, it pre-embeds temperature sensor or arranges it in the easy spontaneous combustion zone through drilling, and determines the points according to the temperature change of the sensor. The advantage is that the external interference is small and the measurement is accurate. If the coal temperature changes and the sensor position is appropriate, it can be effectively detected, although the detection method is accurate and reliable, which makes up for the shortcomings of some of the above detection methods [1], There are some problems worth studying: the arrangement of the sensor is the key to detecting the high temperature region of spontaneous combustion, and the accuracy of the quantity and position determines the effectiveness of controlling the high temperature point in the spontaneous combustion region[2]. There are many methods for the application of temperature detection technology in goaf. Xi-kai Duan uses Fluent to compare and verify the temperature field of the goaf in both forward and reverse directions, determine the location of the hidden fire source in the goaf, and minimize the error of the second comparative analysis[3]. Dr. Yue-ping Qin from China University of Mining & Technology (Beijing) started from the heat source of the goaf, using numerical software to calculate the migration law of the hot air in the goaf under different working surface resistance and original rock temperature, and analyzed the solution results[4]. The above research has only explains the mechanism



of spontaneous combustion hazard in mine goaf from a certain angle, and not take the numerical simulation, laboratory experiment and field test into consideration to determine the “three belts” position of the goaf.

Due to the small temperature coefficient of coal, in order to accurately determine the coal temperature and determine the spontaneous combustion position, a considerable number of sensors must be arranged, so that the optical fiber temperature measurement system with wider measurement range and more convenient construction can be applied to the fire zone temperature detection[5]. The laboratory verification of the optical fiber temperature measurement system shows that the optical fiber temperature measurement technology can accurately and continuously test the temperature change of the goaf, which can provide good data for analyzing and judging the natural ignition law of the goaf [6-7]. The coal quality of the Lao-Shidan mine has a spontaneous combustion tendency. The raw coal has a sulfur content of more than 0.37% and a volatile content of more than 27%. The original coal has a sulfur content of more than 2%, which is prone to oxidation and heat generation, causing the coal seam to expand and rupture, enlarge the oxidation surface and accelerate the oxidation rate. The increase in coal seam temperature creates conditions for spontaneous combustion of coal seams. The residual coal dust and coal gangue in the goaf are prone to spontaneous combustion hazard of the coal seam; The long underground roadway and the relatively complicated ventilation system are easy to cause air leakage since the long mining period of the Lao-Shidan coal mine which significantly increases the risk of spontaneous combustion on the working face[8].

2. Goaf Area Fiber Sensing Detection Technology

2.1. Coal Mine Goaf Fire Monitoring System

According to the actual characteristics of coal mines, the structure of fiber-optic distributed temperature monitoring system in multi-channel coal mine goaf is shown in Fig. 1. The data processing system and the distributed optical fiber temperature measurement host equipment in the ground computer room are mainly placed. After the optical path enters the optical cable, it is disposed along the underground roadway to the 16401 mining working surface. The multi-channel coal mine gob area fiber distributed temperature monitoring system includes: user terminal, data server, distributed fiber optic temperature measuring host, fiber optic connection box, and sensing fiber and fiber guiding device. The distributed optical fiber temperature measuring host is composed of a laser light source, a photoelectric detecting and processing module, an optical system, and a data processing module.

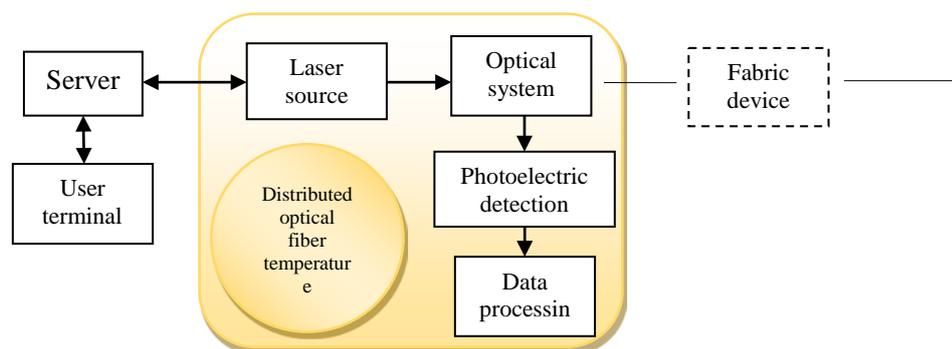
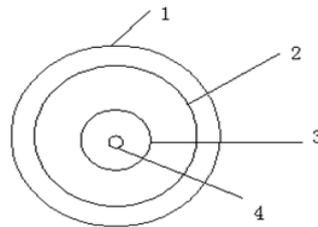


Figure 1. System structure diagram

2.2. Sensing Fiber

The sensing fiber refers to a sensing device that is placed in the goaf to monitor the temperature. Since the sensing fiber may be impacted by the falling objects in the goaf, the fiber should withstand certain tensile and impact forces in addition to ease of production and construction. The coating layer is the first protective layer of the sensing fiber, the armor layer is the second protective layer of the fiber, the gap between the armor layer and the coating layer is reduced to reduce external impact and tensile

force; the tensile layer makes the sensing fiber It can withstand a certain pulling force and smoothly stretch from the wire device after being subjected to the pressure of floating coal. The structure of the sensing fiber is shown in Fig. 2.



1-coating layer, 2-armor layer, 3-tension layer, 4-fiber

Figure 2. Structure of the sensing fiber

3. Gob Area Fiber Sensing Detection Field Application

3.1. Site Plan

Due to the inability to fully maintain the goaf, it is necessary to accurately measure the temperature distribution of the goaf and prevent the fiber from being damaged by coal gangue. Three-way fiber-optic pipelines are used to detect the temperature distribution in the goaf. Among them, 16401 is transported along the 16th lane, and 16401 is used to lay the other two. The optical cable is laid along the coal wall of the roadway and is about one meter away from the bottom plate. It is fixed to the protective net every one meter, The cable is kept at a certain degree of slack when it is fixed; The outside of the working surface shall be laid along the communication cable hook to the substation position. It shall not be tied with the high-voltage cable. The laid fiber cable shall have appropriate slack to prevent damage to the optical cable when accidental force or free fall.

The optical fiber sensing technology is used to detect the temperature change of the goaf in the Lao-Shidan coal mine, and the optical cable is laid out along the two slots in advance. On-line monitoring of environmental temperature changes in goaf, coal mining face and chute, and accurate positioning of high temperature hazard points. The temperature-sensitive cable can be laid along the roadway of the underground goaf to the working area of the goaf, and the temperature distribution trend along the road can be monitored in real time. When the temperature of the goaf is increased, warning information can be issued to provide decision for the production manager to take timely measures to prevent fire. The frame of the temperature monitoring system of the goaf in the 16401 working face is shown in Fig. 3.

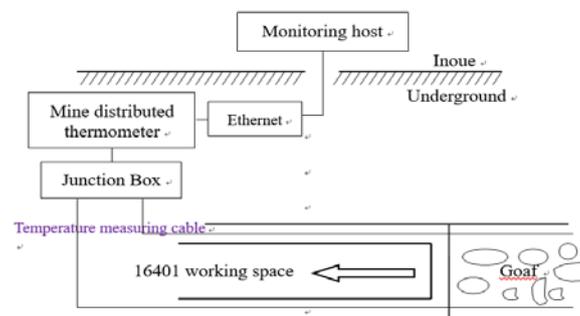


Figure 3. Schematic diagram of the frame of the temperature monitoring system of the goaf in the 16401 working space

3.2. Analysis of Monitoring Results

Table 1 lists the recorded values of the fiber point temperature along the propulsion distance in the goaf of the 16401 working space.

Table 1. Temperature change results of goaf temperature with propulsion distance

propulsion distance /m	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
Temp /°C	33.39	34.54	33.88	34.58	34.35	34.69	34.94	34.3	34.47	34.96	34.88	34.69	34.39	35.26	35.17	37.79

In order to visually observe the temperature change trend, the temperature record in the above table is plotted as shown in Fig. 4.

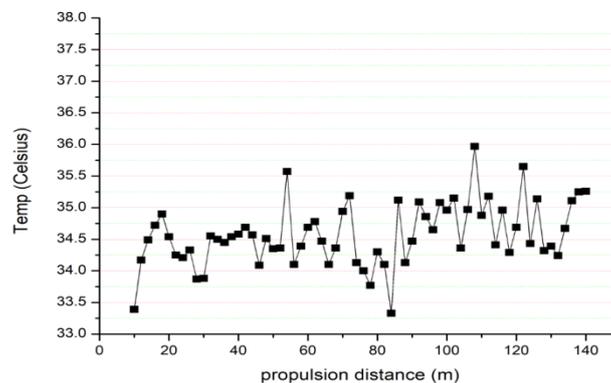


Figure 4. Distribution of the temperature of the fiber measuring point in the goaf along the working surface

In Accord with the figure, with the deep development of the goaf, the temperature fluctuates within a relatively close range from the working space, but the change exist not obvious, and the heat generated by the reaction of the coal can be diffused in time; The surface starts at the boundary of about 54m, and the temperature change amplitude increases relatively. It is explained that the temperature in the oxidative heating zone shows different values according to the progress of the oxidation reaction of coal; the temperature change regression curve starts from about 78m from the working space. Obviously there exist a rise, the oxygen concentration in this area is low, the oxidation reaction of the coal in the goaf is limited, and the accumulation rate of the reaction heat is higher than the heat dissipation rate, forming “Asphyxiation Zone”.

4. Numerical Simulation of Optical Fiber Sensing System in Goaf

The mathematical model is constructed by using CFD software, and the calculation contents of air flow field, oxygen concentration distribution, and gob area temperature field are completed. The calculated model and grid distribution are shown in Fig. 5.

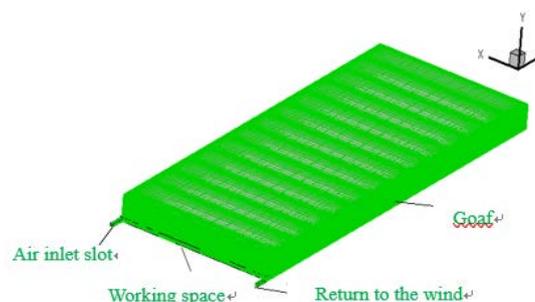
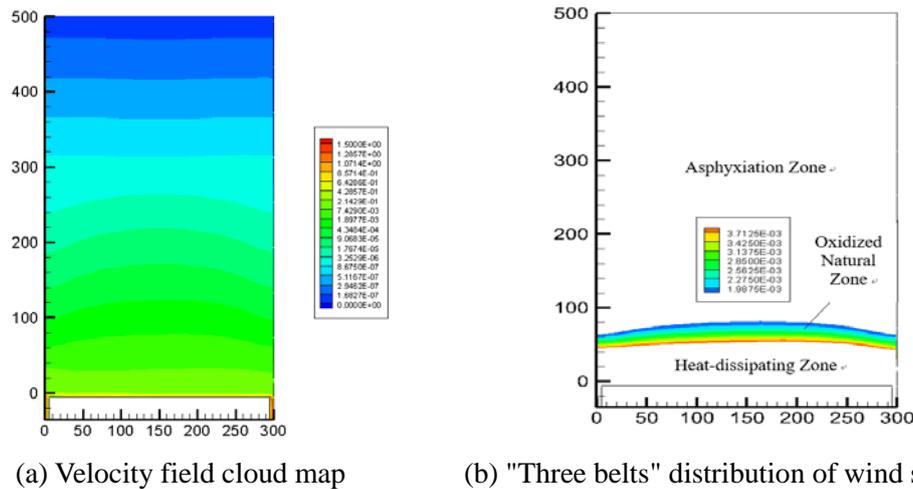


Figure 5. Computational model and meshing

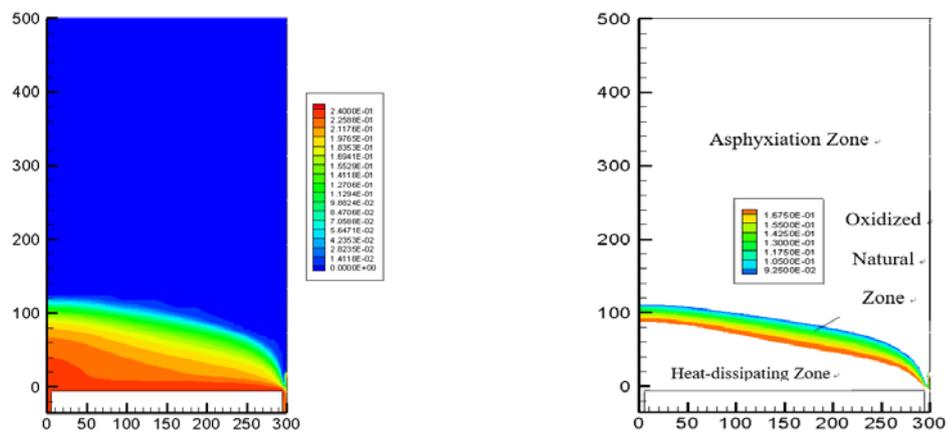
Fig. 6 to Fig. 8 respectively plot the stop velocity and pressure in the vertical direction, 1.5m section from the bottom plate (y=1.5m) and different sections along the depth direction of the goaf (z=10m, 20m, 40m, 80m, 140m) And temperature distribution clouds.



(a) Velocity field cloud map (b) "Three belts" distribution of wind speed

Figure 6. Velocity field cloud map and air leakage wind speed "three belts" distribution (y = 1.5m section)

Combined with the above two figures, it can be seen that the Heat-dissipating Zone is within about 50m from the mining face; 50m~85m is the Oxidized Natural Zone; the region exceeding 85m is the Asphyxiation Zone.



(a) O₂ concentration field (b) Distribution by O₂ concentration "three belts"

Figure 7. O₂ concentration field cloud map (y = 1.5m section)

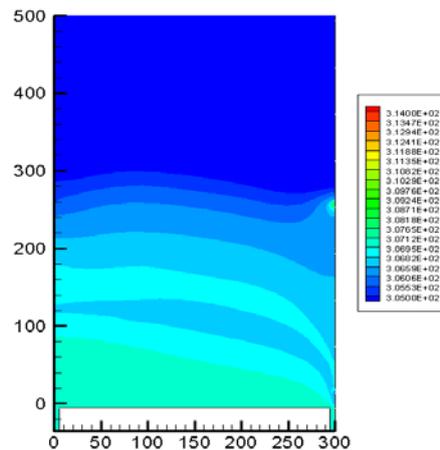


Figure 8. Temperature field cloud map ($y = 1.5\text{m}$ section)

Combined with the O_2 concentration field cloud map and the temperature field cloud map analysis, the Heat-dissipating Zone on the inlet side of the goaf is about 0~90m, the Oxidized Natural Zone is about 90m~110m, and the area over 110m is the Asphyxiation Zone; The average temperature at the Heat-dissipating Zone of the return air side of the goaf is 0~50m, the range of the Oxidized Natural Zone is about 50m~88m, and the area exceeding 88m is the Asphyxiation Zone; The field measured value is input into the mathematical model of CFD software construction, and the simulation result is obtained, and then compared with the measured value of the laboratory, and the comparison result is shown in Fig. 9.

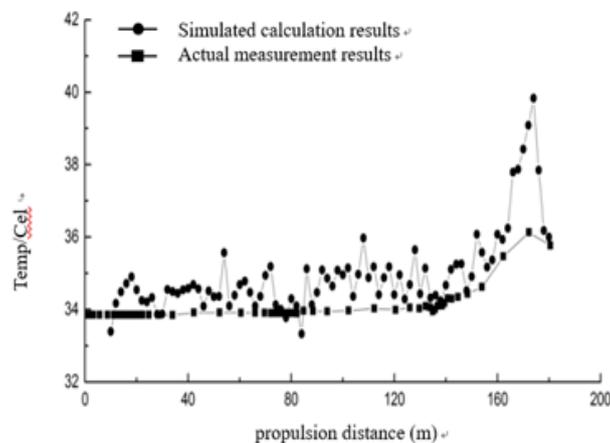


Figure 9. Comparison of simulated results and measured results

It can be seen that there is a difference and a certain correlation between the measured values of the measured values and the calculated values, and the experimental test of the optical fiber temperature measurement effect is performed. Comparing and analyzing the measured data, the error is within $2\text{ }^\circ\text{C}$, which meets the requirements of the temperature measurement accuracy of the goaf, and the change trend is consistent. In the calculation process, it is assumed that most of the air leakage sources under the combined action of fire prevention technology are well protected against plugging, but the air leakage in actual production is higher than that in the calculation, which results in a large impact on wind speed and more heat. Therefore, the temperature rises slowly. As the working surface advances, under actual conditions, the air leaking into the goaf is more, the oxygen is more sufficient, and the heat released by the coal oxidation in the goaf is also much, so the temperature rise is slightly higher than the calculated value.

5. Conclusion

(1) Based on fiber optic technology, the distributed temperature online monitoring system of goaf, real-time online monitoring of the temperature in the goaf, and accurate “three-belts” division of the 16401 working space of the Lao-Shidan coal mine: distance driving work The surface range of 0~54m is the Heat-dissipating Zone, 54m~88m is the Oxidized Natural Zone, and more than 88m enters the Asphyxiation Zone. The distributed optical fiber temperature measurement system can monitor the temperature distribution along the fiber optic cable, and the software can locate and display the temperature distribution of the goaf in real time, effective monitoring of natural fires in the goaf provides a basis for fire safety in coal mines.

(2) Through theoretical analysis, it can be seen that the fiber optic temperature measurement system has its unique advantages and has a self-positioning function, and its fault point is easy to find. Online monitoring can realize real-time recording of temperature at various points along the optical fiber, compared with the traditional electronic sensor. In other words, the fiber optic sensor part does not require a power supply, and its safety and adaptability are greatly improved.

(3) The effective test distance of optical fiber sensing technology is generally above 8km (multimode optical cable) or 20km (single mode optical cable), corresponding to effective test points can reach thousands or tens of thousands, using multi-channel host, its monitoring coverage can reach all electromechanical equipment. For applications with long monitoring distances and many test points, the fiber-optic sensing system shows great advantages.

6. Acknowledgement

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7. References

- [1] Genyin Cheng, Jian Cao, Jingjing Tang, Zhenlei Niu. Application of Distributed Optical Fiber Sensing System in Fire Monitoring of Coal Mine Goaf [J]. Journal of North China Institute of Science and Technology, 2017, 14(02): 4-6.
- [2] Kai Yan. Research and application of key technologies for self-ignition fire zone control of small kiln around coal mine [D]. Taiyuan University of Technology, 2010.
- [3] Xikai Duan. Detection technology of concealed fire source in goaf based on forward and reverse bidirectional simulation[J]. Coal Mine Safety, 2014, 45(10): 51-54.
- [4] Yueping Qin, Hongbo Liu, Weiwei Zhu, Cuixia Wang, Peilin Liu. Numerical Simulation of Hot Air in Goaf of High Temperature Coal Face[J]. Coal Mine Safety, 2011, 42(06): 11-14.
- [5] Can Xu. Application of distributed optical fiber temperature measurement technology in coal mines [D]. Shandong University, 2016.
- [6] Gang Li. New technology for coal spontaneous combustion prevention and control [J]. Science and Technology Information, 2013 (14): 453-454.
- [7] Yujian Zhang. Research on coal temperature monitoring in goaf based on optical fiber temperature measurement technology [D]. Anhui University of Science and Technology, 2015.
- [8] Document in Internet. Lao-Shidan Coal Mine Emergency Plan (Revised Edition) [EB/OL]. (2013.3)[2019.01.16]. <https://www.docin.com/p-1415362913.html>.