Experimental Study on Heat Extraction from Coal Pile by Heat Pipe

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Abstract. Coal spontaneous combustion is one of the major disasters in coal storage and coal transportation. Consequently, coal fire prevention and control technology is one of great significance to the safe operation of coal mines. Heat pipe is a passive heat transfer device by phase change method. Thermal energy can be transported from the underground to the surface continuously by the heat pipe effect, so that it is expected to diffuse concentrated heat and reduce the temperature of the coal pile, which is effective for preventing coal spontaneous combustion. The experiment removing thermal energy from the underground coal is carried out in order to identify the feasibility of the heat pipe heat extraction heat from the coal dump. The results out of the present experimental conditions were shown that the application of heat pipes are contributing to extinguishing coal fire as well as for energy recovery utilization purpose.

1. Introduction

In view of the spontaneous combustion tendency of most coal, the spontaneous combustion of coal piles will be a difficult problem for coal storage and transportation [1,2] and coal mine safety management. Because the process of spontaneous combustion of coal piles is very complicated and influenced by many factors. Based on the coal-oxygen composite reaction [3], related scholars have analyzed the causes of coal spontaneous combustion from different angles, such as Dong Xilin has studied the effect of moisture on the maximum temperature of coal piles [4], and the distribution of air leakage inside the coal pile and the law of coal temperature change [5]. Nordon study on the changes in oxygen and heat during spontaneous combustion of coal piles [6]; Schmal focus on the effect of coal pile porosity on the spontaneous combustion process [7]; Kang Jiasu examined the impact of stacking inclination on coal spontaneous combustion [8]; Akguna examined the effect of coal pile thickness and stacking time on spontaneous combustion of coal pile [9]. And Jing Wei has put forward some practical and feasible measures for spontaneous combustion of coal piles, such as effective barrier to air can prevent spontaneous combustion [10], watering and mechanical compaction can also be used for suppressing coal spontaneous combustion [11]. The prevention and control measures of spontaneous combustion during coal heap storage are mainly based on stratified milling at stacking time, supplemented by manual temperature measurement and repeated rolling, and water spraying cooling treatment is the emergency guarantee as well [12]. In order to solve the problem of spontaneous combustion for the large coal bunker, high-speed water mist spraying and pressure injection of liquid carbon dioxide are usually used as well [13].
In addition, not only coal heap occurring spontaneous combustion to coal itself has a spontaneous combustion tendency, but also it needs to have the following three conditions at the same time [14]: oxygen supply conditions, oxidation time and heat storing conditions. Therefore, it is possible to try to insert a certain number of gravity heat pipes into the spontaneous combustion danger zone in the coal pile, intensifying the heat diffusion of coal piles and destroy the heat storage conditions of spontaneous combustion by heat pipes phase transition advantage, so as to achieving the purpose of preventing and controlling the spontaneous combustion of the coal pile. In order to understand the effect of gravity heat pipe in practical application, we test and observe the change of temperature field of gravity heat pipe when it is inserted inside the coal reactor, and compare and analyze the temperature field change of coal at different horizontal positions.

2. Experimental equipment and conditions

The indoor temperature (Experimental temperature) is 10 °C~25 °C. The pressure of the experiment is standard atmospheric pressure and the height between the ground and the roof is about 4.5~5 meters, in order to keep sufficient space avoiding adverse effects on heat dissipation.

The heat pipe used in the experiment is a curved vertical fin gravity heat pipe with a mass liquid filling capacity 40% of the volume of the heat pipe, gravity heat pipe outer diameter 30mm, pipe wall thickness 3mm respectively. The fins are curved vertical fins with fin thickness 2 mm and inner arc 35.90 mm, the outer arc of the fin 36.95mm, the length of the fin segment 594mm respectively. There are 8 slices of fins, which are evenly distributed on the outside of the pipe wall.

Smokeless pulverized coal is used in the experiment, which can increase the effective contact area between the evaporation section of the heat pipe and the coal. The temperature patrol instrument is connected with the thermal resistance and the data monitoring system to output the corresponding temperature signals of each measuring point and obtain the real-time monitoring data. Platinum-thermal resistance is used in the experiment, and its resistance value is proportional to the temperature. In order to simulate the spontaneous combustion of coal heap more realistically, a 1.5KW circular heating plate is selected to heat up the interior of the coal heap. Based on the purpose of the experimental research, 19 measuring points are arranged at different positions in the coal pile. The layout of the measuring points is as shown in Figure2:
3. Result and Discuss

Under the effect of gravity heat pipe, it is different for the temperature variation law of coal heap high-temperature zone at different distances. In the experiment, a curved vertical fin gravity heat pipe is selected with a good cooling effect and a liquid filling rate of 40%. It is better to analyze the effect of the gravity heat pipe on the internal temperature field of the coal reactor after it is inserted into the coal heap. The experimental data and results are as follows:

3.1 The effect of gravity heat pipe on the lower horizontal temperature

The effect of gravity heat pipe on the horizontal temperature change under the coal storage pile is shown in Figure 4: In the stage of temperature rise, on the one hand, the coal at 100mm is affected by high-temperature heat source, on the other hand, it is also affected by the action of gravity heat pipe. Under the action of heat pipe, the temperature of coal at 100mm cannot be increased indefinitely. At one hour after the temperature at the high-temperature heat source point of the coal reaches its peak, the temperature of the coal at the lower horizontal 100mm reaches a peak of 66.63 ℃, the temperature rises by 23.8 ℃, and then steps into the temperature drop stage. The temperature change trend of coal at 200mm is consistent with the temperature change of coal at 100mm in general, and its temperature reaches a peak of 42.6 ℃ after 2.5 hours application and the temperature rises by 12.27 ℃. Over time, the temperature of the coal at the high-temperature heat source point and at 100mm and 200mm tends to be consistent.

At the lower horizontal position, the effective radius of the gravity heat pipe is one of the main factors affecting the coal at 100mm and at 200mm. The effect of gravity heat pipe on coal within 100mm is greater than the effect of coal between 100mm and 200mm. Before the temperature of the high-temperature point drops to 50 ℃, the gravity heat pipe is in working state, and the heat transfer mode is mainly transferred to the condensation section through the liquid phase change of the gravity
heat pipe working fluid. The effect of gravity heat pipe on coal at 100mm and 200mm is greater than the coal at the high-temperature heat source point when the temperature drops to 50 ℃.

3.2 The effect of heat pipes on the middle horizontal temperature change

![Figure 4. The change of middle horizontal temperature](image)

The effect of gravity heat pipes on the horizontal temperature change in the coal storage pile is shown in Figure 5. The distance between the middle horizontal position and the position of the high-temperature heat source point is 220mm. Because of the low thermal conductivity of coal, heat transfer is slow. After inserting the gravity heat pipe, the pipe wall provides a channel for heat transfer, so the temperature of the coal at a distance of 100 mm from the heat pipe gradually rises. The coal at 100 mm reached its peak in about 12 hours. At this time the gravity heat pipe is in the transition stage, the transferred heat gradually decreases, and then the coal at 100mm begins to enter the cooling stage. During this time, the coal at 200 mm is still in a state of natural cooling, and as the temperature difference with the surrounding coal becomes larger, heat is transferred from the side close to the heat pipe to the coal at 200 mm. The temperature of the coal at 200mm peaked around 17 hours, and then it also went into the cooling phase.

Although the gravity heat pipe transfers heat at the point of high-temperature heat source of the coal, the pipe wall provides a passage for heat transfer. However, it can be calculated from the measured data that the maximum temperature difference of the coal at the middle horizontal position is 1℃~2℃. The gravity heat pipe is dormant when the coal at the high-temperature heat source point is in a stable and flat stage. At this time, the heat transfer function of gravity heat pipe is mainly the heat transfer of pipe wall. As long as the temperature inside the coal is higher than the indoor temperature, the heat can be transferred through the pipe wall, and eventually the temperature of the coal tends to be consistent with the room temperature.

3.3 The effect of heat pipe on the upper horizontal temperature

![Figure 5. Upper horizontal temperature change](image)
The effect of gravity heat pipe on the horizontal temperature change on the coal storage pile is shown in Figure 6. The upper horizontal layer is 70mm from the coal surface, which belongs to the cooling zone in the “three belts” of the coal heap, and the air circulation is good, and the temperature of this layer is greatly affected by the indoor temperature. The temperature of coal at 100mm and 200mm is basically the same as the rate of rise and fall. Affected by the temperature of the wall of the gravity heat pipe, the temperature of coal at 100 mm is higher than the temperature of coal at 200 mm. The increased temperature of coal at 100 mm is also slightly higher than the increased temperature of coal at 200 mm, while the temperature drop of coal at 100 mm is slightly less than the decrease of coal at 200 mm. The temperature of coal in the upper horizontal position is in equilibrium within 5-10 hours. At the same time, it can also be reported that when the outdoor temperature rises, the temperature of coal increases, and when the room temperature drops, only when the room temperature is lower than the coal heap temperature, the temperature of the coal body will decline.

4. Conclusions
The article analyzes the effect of gravity heat pipe on the heat dissipation of coal piles, and starts from the reality, by adding high-temperature heat source points to simulate the temperature of the coal pile center, it should be heated from bottom to top to form a temperature field that drops with the height rise temperature, which is consistent with the reality.

(1) It can be seen from the experimental data and the chart that the heat dissipation effect of the gravity heat pipe on the coal at different horizontal positions is different after being inserted into the coal pile. The gravity heat pipe has the most obvious effect on the coal in the lower horizontal position. The temperature of the coal is not always affected by the high-temperature heat source due to the action of the gravity heat pipe.

(2) Although the effect of the gravity heat pipe on the coal in the middle horizontal position is not greater than that in the lower horizontal position, the gravity heat pipe acts to strengthen the heat transfer at the middle horizontal position, so that the coal at this position is more quickly absorb the heat of the high-temperature coal in the horizontal position, and then transfer this part of the heat to the coal in the upper horizontal position faster. It prevents the risk of spontaneous combustion of coal caused by the accumulation of internal heat in coal for a long time.

(3) The coal in the upper horizontal position is greatly affected by the indoor environmental temperature, and the effect of the gravity heat pipe on the coal at this position is the least obvious. When the indoor temperature is lower than the temperature of the coal pile, the temperature of the coal pile begins to decrease.

Acknowledgments
The financial was partially supported by National Natural Science Foundation Funded Project (51504188), which were greatly acknowledged.

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