International Journal of Natural Resources and Environmental Studies
ISSN: 3006-2012 (Print), ISSN: 3006-0834 (Online) | Volume 6, Number 1, Year 2025
DOI: https://doi.org/10.62051/ijnres.v6n1.08
Journal homepage: https://wepub.org/index.php/IJNRES/index

Research Status of High Temperature Mine Cooling Technology at Home and Abroad

Xiangwei Li

School of College of Energy Science and Engineering, Henan polytechnic university, Jiaozuo, China

ABSTRACT

With the gradual mining of the mine to the deep, the mine will face the problem of heat damage, and the high temperature of the working face will seriously affect the production efficiency of the mine. Therefore, it is necessary to adopt the corresponding cooling measures to cool the high temperature mine. This paper aims to summarize the current high temperature mine cooling technology at home and abroad, analyze its advantages and disadvantages, and provide corresponding technical application ideas for high temperature mine cooling.

KEYWORDS

Deep Mining, Mine Heat Hazard, Falling Net Temperature Technique.

1. INTRODUCTION

At present, the traditional treatment methods of mine heat damage can be divided into two categories. One is non-mechanical refrigeration cooling method, including ventilation cooling, heat insulation grooming, individual protection and so on. The other is mechanical refrigeration methods, such as gas power generation refrigeration cooling, heat pipe cooling and compressed air refrigeration cooling and carbon dioxide refrigeration cooling. Increasing the amount of mine ventilation to take away the underground waste heat is the oldest and most widely used method of mine cooling. However, due to the constraints of working face inlet air temperature, wind speed and other conditions, the applicable conditions are limited. With the increase of mining depth, non-artificial refrigeration cooling technology can no longer meet the cooling needs of the working site, in order to create a suitable working environment in the mine. In South Africa, West Germany, Japan and the former Soviet Union, the research on artificial refrigeration technology of mine air conditioning has been carried out since the 1970 s. According to the layout, it can be divided into underground centralized, ground centralized, joint centralized and underground local decentralized. The research mainly focuses on the development of coolers and air coolers. Nowadays, after years of development, mine cooling technology at home and abroad is no longer limited to cooler cooling, cooling technology diversification, the following lists a series of cooling methods and explains its advantages and disadvantages.

2. HEMS COOLING TECHNOLOGY

High Temperature Exchange Machinery System (HEMS) is a high temperature mine heat damage cooling technology proposed by He et al[1]. It uses the mine gushing water to extract cold energy from the gushing water through a series of refrigeration systems, and then uses the extracted cold energy to exchange heat with the high temperature air of the working face to reduce the ambient temperature and humidity of the working face.

HEMS technology utilizes the gushing water of underground mines. However, due to the scaling of pipelines caused by the circulation of groundwater in the system, it seriously affects its normal work. Therefore, it is necessary to descaling the system regularly. Moreover, HEMS technology does not cure the source of heat damage. It can only cool the working face and reduce the outlet air temperature and relative humidity, which cannot effectively improve the thermal comfort in the mine. Especially for workers, this technology has certain limitations. At present, the use of natural cold sources and the transfer of mine heat and use are two prominent directions.

3. LIQUID CO_2 PHASE CHANGE REFRIGERATION TECHNOLOGY

The liquid gas phase change refrigeration technology is to use the phase change absorption heat when the liquid gas evaporates to cool down. Liquid CO_2 phase change refrigeration technology[2] uses liquid CO_2 as the refrigeration source, and sends the air flow and liquid CO_2 into the heat exchanger through the ventilation system and the liquid supply system respectively. The CO_2 evaporation absorbs heat to reduce the temperature of the air flow into the working face, and sends the low-temperature air flow to the place where it needs to be cooled. The cooling effect is very obvious, and the gaseous CO_2 is sent to the goaf to prevent the spontaneous combustion of the residual coal in the goaf.

The technology has a significant cooling effect on the working face, with less investment, simple device structure and simple operation. It can quickly realize the cooling of the working face, realize the cooling of the mine and suppress the mine fire at the same time. Liquid CO_2 phase change refrigeration technology can effectively cool the cooling site, but at the same time, the technology also has drawbacks. The liquid CO_2 refrigeration effect is limited, and the gaseous CO_2 gas is not recycled, resulting in an increase in CO_2 concentration, which may cause the occurrence of suffocation events in underground workers.

4. DIRECT EXPANSION HEAT PUMP COOLING TECHNOLOGY

Heat pump is a kind of equipment that transfers the energy of low heat source to high heat source, including evaporator, throttling device, compressor and condenser. The cooling source is added to the system, and the process of heat absorption and heat release is carried out by using the phase change of the coolant, so as to cool the mine.

The direct expansion heat pump technology[3] is to extract ore heat energy through a self-made collector tube, and then use the heat exchange function of the condensation section to replace the heat energy into the cooling water for ground heating planning. The direct expansion heat pump technology uses the mine heat source to supply the ground building units. On the one hand, it achieves the effect of mine cooling, and on the other hand, it utilizes the geothermal resources.

Direct expansion heat pump technology can not only cool the mine, but also effectively use geothermal energy to supply hot water to the ground, which is energy-saving and environmentally friendly. Compared with other heat pump systems, this direct expansion heat pump system has the advantages of simple structure, convenient operation, low energy consumption and environmental protection. However, this kind of equipment has limited cooling effect on rock mass, and can not absorb the heat energy of surrounding rock in a large range, and can not meet the cooling demand of working face. If it is used in practical engineering, it needs further transformation and strengthening.

5. VORTEX TUBE COOLING TECHNOLOGY

Vortex tube cooling technology[4] is simple, convenient and easy to operate. It uses air compression to achieve the purpose of refrigeration. It does not need heat sink or heat exchanger inside. It does not need a long start-up time like other equipment, but can achieve the effect of instantaneous refrigeration. As long as the air is compressed, it can be cooled. Its structure is extremely simple, but the cooling capacity is low, and it can only be applied to a small part of the closed area to cool down.

The vortex tube is mainly composed of shell, nozzle, vortex chamber, separation orifice plate, cold end tube, hot end tube and temperature control valve. When the vortex tube works, the high-pressure gas from the gas source expands and accelerates in the nozzle, and then enters the vortex chamber almost in the form of free vortex along the tangential direction, and rotates at high speed in the vortex chamber to produce strong vortex flow, resulting in energy separation effect, which is finally separated into two parts with different temperatures. The airflow temperature in the center is lower than the inlet airflow temperature, which is called cold airflow, and this part of the airflow flows out from the cold end. The airflow temperature in the outer layer is higher than the inlet airflow temperature, which is called hot airflow. It flows out from the temperature control valve through the hot end tube, and the ratio of cold and hot airflow can be adjusted by the temperature control valve, so as to obtain different refrigeration effects.

6. GENERALIZE

This paper systematically reviews the four mainstream cooling technologies in the high temperature control of mines at the present stage. By comparing and analyzing their thermodynamic characteristics, applicable scenarios and engineering limitations, it reveals the energy efficiency bottlenecks of different technical paths in the deep mining environment, and then proposes the ' active cooling-waste heat recovery ' collaborative governance framework, which provides a theoretical basis and technical path reference for breaking through the traditional single technical model and building a green and efficient heat damage prevention and control system.

REFERENCE

[1] He manchao, Xu min, HEMS deep well cooling system development and heat damage control measures[J]. Journal of Rock Mechanics and Engineering, 2008,(7).1353-1361.

[2] Song Dongping, Zhou Xihua, Li Jingyang, et al. Cooling technology of liquid CO2 phase change refrigeration in high temperature mine [J].Coal Science and Technology, 2017,45(10):82-87.

[3] Hou Jiangli, Wu Lingling, Luo Xuzhao, et al. Deep well heat collecting and cooling experimental system based on direct expansion heat pump technology[J]. Non-ferrous metal engineering, 2020,10(3):62-68.

[4] Zhang Yang, Xin Song, Ji Jianhu, et al. Application of vortex tube cooling technology in coal mine microclimate cooling [J]. Mining safety and environmental protection, 2018,45(1):107-111.