Postprint: Analysis of Cooling Effect of Prefabricated Convection-Radiation Cooling System in Deep Mine Stopes

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Abstract

Artificial refrigeration cooling technology is currently one of the most effective methods for deep mine heat hazard control. At present, cooling methods are dominated by all-air cooling, which exhibits numerous problems such as the "cold near, hot far" cooling effect and enormous energy consumption, deviating from the national green mine development strategy. The prefabricated convection-radiation cooling system is a local cooling device that integrates support and cooling functions, which can be installed in cold-demand areas of the working face to create a locally comfortable thermal environment. To investigate the cooling effect of the prefabricated convection-radiation cooling system, theoretical analysis and CFD simulation methods were employed to obtain a mathematical model of the system' s cooling capacity; the system' s cooling mechanism was analyzed and operating conditions were optimized; the cooling effect of the system was evaluated using the 7119 working face of Zhangshuanglou Mine as a case study. The results indicate that: (1) The integration of the prefabricated high-temperature mine convection-radiation cooling system with the side-wall support system enables simultaneous roadway excavation, support, and environmental improvement, thereby enhancing production efficiency and environmental comfort. (2) The optimal operating conditions for the prefabricated high-temperature mine convection-radiation cooling system are: coolant flow velocity of 0.2 m/s, inlet air velocity of 0.6 m/s, air outlet height set at 60 mm, and system cooling capacity of 269 W. (3) The cooling effect of the prefabricated high-temperature mine convection-radiation cooling system (meeting comfort requirements) is improved by 31% compared to the roadway all-air cooling method, can satisfy the comfortable environmental requirements for adaptive workers in mining faces within a mining depth of 2000 m, and the system can maximally ensure the thermal safety of miners. Meanwhile, according to on-site cooling demands, the equipment installation spacing can be adjusted to perform local environmental control, substantially saving

cooling energy consumption. This research can be used to guide local environmental control in mine working faces, efficient and precise cooling of intelligent minimally-manned working faces, and occupational health protection for miners, fully responding to the national green mine development strategy and contributing to the achievement of national dual-carbon goals.

Full Text

Analysis of the Cooling Effect of a Modular Convective-Radiative Cooling System in Deep Mine Stopes

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Abstract

Artificial refrigeration cooling technology is currently one of the most effective methods for deep mine heat hazard control. However, existing cooling methods are dominated by all-air systems, which suffer from problems such as non-uniform cooling effects (“cold near, hot far”) and excessive energy consumption, contradicting the national green mining development strategy. The modular convective-radiative cooling system is a localized cooling device that integrates support and cooling functions, which can be installed in cold-demand areas of the working face to create a comfortable local thermal environment. To investigate its cooling effect, this study employs theoretical analysis and CFD simulation to develop a mathematical model of the system’ s cooling capacity, analyze its cooling mechanism, and optimize operating conditions. The cooling effect was evaluated using the 7119 working face of Zhangshuanglou Mine as a case study. Results indicate: (1) Integration of the modular convective-radiative cooling system with the sidewall support system enables simultaneous roadway excavation, support, and environmental improvement, enhancing both production efficiency and environmental comfort. (2) The optimal operating conditions are: coolant flow velocity of 0.2 m/s, inlet air velocity of 0.6 m/s, outlet height of 60 mm, and system cooling capacity of 269 W. (3) The system’ s cooling effect (meeting comfort requirements) is 31% higher than that of conventional all-air roadway cooling methods, and can satisfy comfortable environmental requirements for adaptive workers in stopes within 2000 m mining depth while maximizing thermal safety for miners. Furthermore, equipment installation spacing can be adjusted according to on-site cooling demands for localized environmental control, substantially reducing cooling energy consumption. This research can guide localized environmental control in mine stopes, efficient and precise cooling of intelligent minimally-manned working faces, and occupational health protection for miners, fully supporting the national green mining development strategy and contributing to the achievement of national dual-carbon goals.

Keywords: deep mines; modular convective-radiative cooling system; cooling effect; wet-bulb globe temperature (WBGT); computational fluid dynamics (CFD)

Note: Figure translations are in progress. See original paper for figures.