

STUDY ON THE THERMAL ENVIRONMENT OF HEADING FACES IN UNDERGROUND MINES

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論文要旨

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論文題名 STUDY ON THE THERMAL ENVIRONMENT OF HEADING FACES IN UNDERGROUND MINES (地下鉱山における掘進切羽の熱環境についての研究)			

論文内容の要旨

The extraction of minerals at great depth with higher-powered machinery to increase production has imposed an increased burden on ventilation and cooling systems to maintain an acceptable thermal environment. Geothermal hazards will significantly affect the miners' health and safety. For example, in China, 53% of the Chinese coal deposits are buried in the earth below 1000 meters. As the rapid growth of energy demand, the exploitation depth of Chinese coal mines increases average 10 meters every year. Now about 50 mining fields are mining at the depth of below 700 meters. Most of them are mining even below 1000 meters. Hence, most of mines are turning to face the complex and hot mineral deposits. It is considered that the underground thermal environment will become more serious in the near future. In this situation, it may be required that large centralized cooling facilities should be installed. For the mining plan, in order to design optimum mine ventilation and cooling systems, it is a basic requirement that the air temperature and humidity of the airflow must be simulated by mine climatic simulation programs with sufficient accuracy.

Numerous mine climatic simulation programs for heading faces in underground mines have been developed to simulate the thermal environment. This dissertation has been carried out based on one of the simulation programs (KDUCT), a climatic simulation program for heading faces. In order to achieve the accurate simulated results, the correct *in situ* data should be input. This dissertation aims to establish the values of wetness fraction and the heat sources in heading faces for the simulation.

Chapter 1 is the introduction of this dissertation. With the increase of mining depth, the geothermal hazards have become more serious than before. The importance of the climatic simulation for the underground thermal environment has been introduced in this chapter. In order to achieve the accurate simulation results, the accurate input data is necessary. The purpose of this dissertation which aims to establish the accurate input data for the important parameters has been pointed out.

Chapter 2 introduces the essential characteristics of subsurface ventilation systems based on whole mines and main airflow routes. If the ventilation systems are not sufficient to remove the heat, the cooling systems must be installed. In this chapter, the design of mine cooling systems and the methods of distributing cooling air to the working areas has been discussed. A climatic simulation program should be used to answer the question that how much heat can, or should, be removed by ventilation and how much by cooling systems.

Chapter 3 presents the previous research on heat source, concept of geothermic gradient, measurements of rock thermal conductivity and determination of heat transfer coefficient. For the measurements of rock thermal conductivity, many researchers have already carried out a number of laboratory tests for the determination of the thermal conductivities of coal, shale, and sandstone samples. However, some

researchers pointed out that it is preferable to measure rock thermal conductivity *in situ*. For the determination of heat transfer coefficient, several researchers have proposed the equations and simulation. In the second part of Chapter 3, the calculation of air temperature in a ventilation network has been introduced. The exact solution, the approximate solution described as G value equation and finite difference method have been introduced in this part. Then the theoretical basis behind the simulation programs for thermal environment in heading faces has been briefly reviewed. Now the finite difference method is one of the standard algorithms employed in the simulation programs.

Chapter 4 describes fundamental studies on a practical method for the simulation of air temperature and humidity along wet airways. The concept of wetness fraction has been introduced. Discussions have been made on the mathematical expressions of heat and moisture transfer at an airway surface by using the concept of modified air temperature and wetness fraction. A series of detailed parametric studies analysis have been carried out. It can be concluded that variation in wetness fraction, rock thermal conductivity and heat transfer coefficient could have a significant impact on the climatic simulation results. In order to establish the values of wetness fraction, *in situ* measurements have been undertaken in Hishikari Mine. The equation for wetness fraction should be modified from the view of heat balance between the airway and air duct. The improvement on the equation shows good agreement if the values of heat transferred from airway to the air duct are known. Then the values of wetness fraction can be calculated accurately even the heat exchanger is working.

Chapter 5 presents an *in situ* measurement carried out in a heading face of Hishikari Mine. Heat from fragmented rock, explosives and diesel equipment have been investigated by employing the measured results. The measured results show that heat load from fragmented rock decreased very slowly. An equation for describing the process of heat exchange has been presented in this chapter. With the help of this equation, features of air temperature variation can be simulated. In this model, air temperature is subject to exponential decay. This equation can be also widely used in other heat exchange systems. Heat produced by diesel equipment has been also discussed in this chapter. Both the *in situ* measurement and theoretical calculation showed about 105 kW of heat could be produced by the nominal 144 kW diesel equipment. The heat that was produced by explosives caused a peak heat load on the ventilation systems. According to the *in situ* measurements, 4% of heat appeared in the blasting fumes while the rest was retained in the rock. These results can contribute to the improvement of climatic simulation for heading faces.

Chapter 6 presents an analysis of climatic simulation in heading faces by simulation programs. If the simulation programs did not consider the transmission of heat by moving water inside the rock, the strata heat could be underestimated by using the value for the rock thermal conductivity measured in laboratory. Then the dry and wet bulb temperatures could be underestimated. Hence in the case of the inputting value of rock thermal conductivity for running simulation programs, the sensitivity analyses show that when there is high virgin rock temperature with hot underground water inside the rock, about three times higher than the measured value by laboratory test is required for the accurate simulation. In order to verify the value is correct, a future *in situ* measurement is needed and a new simulation programs should be improved to consider the transmission of heat by moving water inside the rock.

Chapter 7 summarizes the conclusions of this study and recommendations for further study.