International Journal of Mining Science and Technology 24 (2014) 683–688

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Physiological responses of people in working faces of deep underground mines

You Bo [a,b,*], Wu Chao [a], Li Ji [c], Liao Huimin [a]

[a] School of Resources and Safety Engineering, Central South University, Changsha 410083, China
[b] School of Energy & Safety Engineering, Hunan University of Science & Technology, Xiangtan 411201, China
[c] Changsha Institute of Mining Research Co. Ltd., Changsha 410012, China

ARTICLE INFO

Article history:
Received 28 October 2013
Received in revised form 1 January 2014
Accepted 28 March 2014
Available online 20 August 2014

Keywords:
Deep mine
Confined space
High temperature and high humidity
Simulation experiment
Human physiological index

ABSTRACT

The research studied the influences of high temperature, high pressure, high humidity, noise and other harmful factors in mining conditions on the people health and safety, and investigated the impacts of confined environmental on human physiology factors, including temperature, humidity, noise, pressure, toxic and harmful gases in terms of environmental characteristics in underground mines and an artificial intelligence system for simulation of the environment in a confined space of deep mines. Our results show that the systolic pressure, diastolic pressure, mean pressure, heart rate, respiratory rate, typing test speed and memory level percentage are negatively correlated with temperature value, and positively correlated with humidity value; the human temperature and weight are positively correlated with temperature value, and negatively correlated with humidity value. This research lays the foundation for the study of interaction between the deep confined space environment and safety behavior.

1. Introduction

The special work environment is an important problem regarding the safety and health of mining industry in the process of mine production [1–4]. High temperature, high pressure, high humidity, noise, toxic and harmful gases and other special environmental factors form a severe environment of deep confined space, in which the human health are threatened and work rate of workers is greatly reduced [5,6].

At present, the working environment of high temperature and high humidity is ubiquitous in the process of mining production. Several researchers also studied the impact of high temperature and high humidity environment on human physiological health. Researchers carried out human thermal endurance experiment and the research of human comfort in high temperature and high humidity environment, and analyzed the impact of extreme environment on the human body and preventive measures [7–11]. In this study, the environment in deep confined space of mines is stimulated by the newest artificial intelligence equipment, which enables the study of the physiological response of human to severe environment in deep confined space of mines. Besides, this paper tested and analyzed the human physiological parameters in the moving process of high temperature and high humidity simulation, and explored the impact of extreme environment on the rules of human physiological parameters. This research provides the scientific basis on protecting human health and improving human work efficiency [12–21].

2. Experimental platform

The research was conducted based on an artificial intelligence system which stimulated the environment and safety conditions in deep confined space of mines. The system is composed of two modules: one is to adjust environmental parameters and to simulate people operation, and the other is to determine the environment and the tested human factors. The first module consists of nine adjusting sub-systems which control temperature, humidity, air pressure, noise, lighting, air velocity, poison gas concentration, human physiology and psychology parameter measuring and communication respectively. The second module includes the devices for monitoring the parameters of the temperature, humidity, noise, pressure, toxic and harmful gases concentration, dust concentration, and the human factors of the blood pressure, heart rate, respiratory rate, etc. The operational personnel can monitor the cabin environment and the human factor parameters in the cabin from different angles through the video image transmitted from inside, which enabled the whole experiment process being monitored in

* Corresponding author. Tel.: +86 15111340906.
E-mail address: lgilstyoubo@sina.com (B. You).

http://dx.doi.org/10.1016/j.ijmst.2014.03.024
2095-2686/

a real-time basis [22]. Figs. 1–3 show the appearance picture and functional relationship of the artificial intelligence equipment.

3. Design of experimental scheme

3.1. Experimental conditions

The experiment cabinet temperature was set to four levels without temperature and humidity adjustment: temperature as 25 °C and 50% humidity, 28 °C and 60% humidity, 35 °C and 70% humidity, and 38 °C and 78% humidity. In order to simulate the environment of deep restricted space, all lights in the cabinet were turned off to form a dark environment. Wind speed and the noise were set at 5 m/s and 90 dB, respectively. Heating and humidifying start at the same time, and air and noise stabilize at the set value. Once the temperature and humidity stabilize at pre-settled value, heating and humidifying equipment will stop, indicating ready of experimental condition. The temperature and humidity is automatic controlled to adjust the temperature and humidity automatically with the set value to satisfy the experiment condition.

Fig. 1. Appearance picture of the environmental simulation equipment.

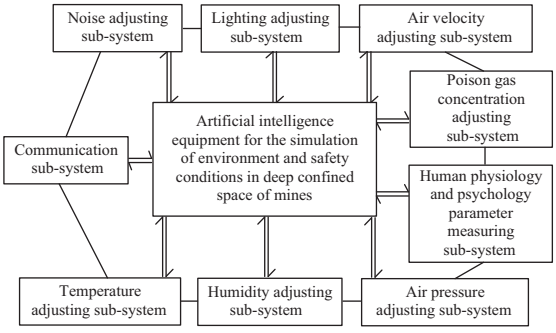

Fig. 2. Module for adjusting environmental parameters and for simulating people operation in the cabin.

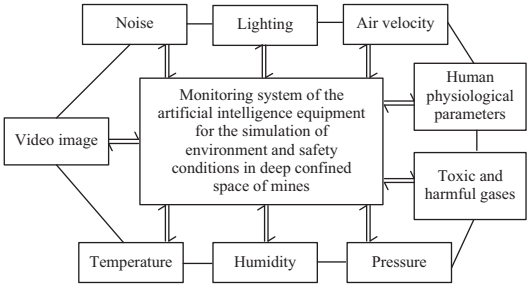

Fig. 3. Module for determining the environment and human factors in the cabin.

3.2. Personnel selection

In this experiment, 8 experimenters with the age from 23 to 26, are selected from Central South University, including seven male classmates and one female. The sample personnel are all with good physical condition by inspecting their heart rate and blood pressure, and without any genetic disease history. A good diet and sleep were served before experiment.

3.3. Experimental procedures

(1) Measure the blood pressure, heart rate, respiratory rate, body temperature, weight and physiological index value of the tester before the experiment, and conduct a typing test experiment and a memory experiment. The apparatus for measuring human physiological index value is G3D multi-parameter patient monitor.
(2) Then do the running exercise on a treadmill three times in the cabin with a set temperature, humidity, noise, light, wind speed and other environmental conditions, and adjust the speed properly to meet his degree of adaptation in the process of running every ten minutes in each exercise. The average speed is 5 m/s, and the total distance is 1.5 km.
(3) Measure the physiological indexes of the blood pressure, heart rate, respiratory rate, body temperature and weight after each exercise.
(4) It can ask the tester his condition in the process of physiological index measurement after running, such as whether his emotional state is energetic, a little relaxed, a little tired, very tired, unbearable, whether he has the feelings of nausea, vomiting, stomach pains, and satisfaction extent of self-feeling.
(5) After the measurement, the tester will do the typing and memory tests. After each testing, the tester should get enough rest before the running experiments in the next level environment.
(6) Typing test experiment, do the English articles typing test by using the Kingsoft typing software. Tester has to do the typing test for 5 min. The first input content shall prevail in the process of typing, not allowed to be deleted or modified, and in the final, the tester records the typing speed. Do this test before and after the exercise relatively.
(7) Memory experiment: Table 1 shows 20 people's names in layout, and Table 2 presents the names removed the surnames on the basis of Table 1, but the sequences are disrupted. Take 5 min to remember these 20 names, then stop, and read Table 2, fill the original surname of these 20 people from memory. Do the memory test before and after exercise relatively, and compare the scores.
Scoring standard: each correct answer records one point, and wrong answers do not record point nor deduct point. According to the scores obtained, check the evaluation form (Table 1), and calculate the text memory capacity level.
(8) Heatstroke plan: it shall stop the experiment immediately if the tester feels unwell, breathing difficultly and other symptoms in the process of experiment, and take him to the well-ventilated outdoor environment to have a rest, and supplement water. The tester shall be quickly moved to a cool and ventilated place, then unbutton his shirt and have a supine rest, if it is found that the tester has heatstroke symptoms like headache, dizziness, thirst, flushing, etc. The testers apply head with a cold towel, or wash body with 30% alcohol for cooling, and drink some light salt water or soft drinks.