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Prediction of Safe Working Hours of Pumping Station Drivers in Coal Mine

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Abstract

The unsafe behavior of operators in coal mines is one of the key risk factors leading to accidents. It is very dangerous to work underground for a long time, which is easy to increase the fatigue and physiological and psychological burden of operators, resulting in safety accidents. Therefore, it is important to pay attention to how to prevent operator fatigue and unsafe behaviour, thereby preventing accidents in coal mines. It is an effective means to reduce the physical and mental injury and accident rate caused by an unfavourable working environment to pumping station drivers through a reasonable arrangement of working time. To predict the safe working hours of pump station drivers, the field measured physiological index data of a mine face pumping station driver in Henan Province, China was taken as an example, the sensitive physiological indexes such as systolic pressure, diastolic pressure, and heart rate of the underground pumping station driver were calculated by using the grey predictive model GM (1,1). The warning range of each index was determined. Results show that according to the principle of minimum value triggered by a threshold value of physiological indexes, the reasonable safe working hours of pumping station drivers in a fully mechanized mining face is 5.7h. The conclusions provide a reference for reasonably arranging the working time of the pumping station driver and have certain guiding significance for reducing human errors and safe production of coal mining enterprises.

Keywords: Intelligent prediction, Safe working hours, Unsafe behavior, Physiological indexes

1. Introduction

With the improvement of coal mining technology, comprehensive mechanized coal mining is the main development direction of China’s coal mining technology [1]. Especially with the development of modern industry and the progress of science and technology, more high-power, high-speed machinery and equipment are used in coal mine production [2]. Owing to much machinery and equipment, narrow working space, strong ventilation direction, heavy equipment load, and other reasons, the fully mechanized mining face of the coal mine has formed its special environmental pollution [3]. The poor underground working environment has a serious influence on the physiology and psychology of operators [4, 5]. In addition to increasing the incidence of occupational diseases, it affects the reliability of operators’ behaviors, leading to the occurrence of unsafe behaviors. Statistical data show that although the number of coal mine accidents shows a general trend of decline, accidents caused by human error account for 88.4% of the total number of accidents in fully mechanized coal face [6]. Human is a weak link in coal mine production. According to the analysis of human accidents, fatigue is the main cause of human accidents [7, 8]. Therefore, the reasonable arrangement of working time and the recovery from fatigue are effective means to reduce the physical and mental injury caused by the unfavorable working environment to the pumping station drivers and lower the accident rate.

However, most of the existing research on coal mine safety starts from the direction of gas and dust explosion, and many study the code of conduct of operators and the prevention and control of occupational diseases from the perspective of human accidents. Attention to the connection surface of man and ring in the underground coal mine from the perspective of system engineering is lacking, and the research on the influence of the unfavorable working environment on the safety behavior of operators is neglected. Therefore, this study, aiming at the deficiency of this research, comprehensively analyzes the change rule of the physiological and psychological indexes of pumping station drivers in the complex environment of coal mine from the perspective of “human-Machine-Environment” system engineering and calculates the safe working hours of pumping station drivers by using the grey predictive GM (1,1) model. It provides a decision-making reference for reducing the unsafe behavior of coal mine operators and improving the safe operation of the coal mine system.

2. State of the Art

In the study of unsafe behavior of coal mine operators, most of the existing literature conducts modeling analysis from the perspective of operator behavior reliability to determine the effect of various factors on personnel reliability. For example, based on the fuzzy mathematical method, Feng proposed a fuzzy comprehensive evaluation model applicable to the reliability study of coal mine operators [9]. He et al. compared 7 commonly used human reliability analysis methods and proposed 12 standards for the HRA method comparison [10]. Through the study of human accidents in coal mines, Chen et al. put forward the

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prediction and evaluation method of human errors of coal mine operators and evaluated the operation reliability of operators [11]. Wang et al. combined growth theory and grey correlation theory to quantify the control mode in the cognitive reliability and fault analysis method and established the Human Error Probability (HEP) and grey correlation degree relation function model for human factor reliability analysis in coal mine production [12]. Massimo used the fuzzy cognitive mapping method to study the factors influencing human reliability and their relationships [13]. Katrina introduced a hierarchical setting that can be used for qualitative and quantitative analysis of the practical performance influencing factors (PIF) of HRA and explained the setting principles of PIF hierarchy [14]. Podofillini applied the Bayesian method in the prediction of human error probability and believed that this method could further refine the human factor reliability algorithm [15].

In view of the research on the working time of coal mine workers, the existing literature is mostly analyzed from the perspective of sociology or epidemiology to provide a certain reference for the existing safety management system. For example, Dong et al. [16] analyzed the measurement method for detecting the physiological and psychological fatigue of miners from subjective and objective aspects based on the actual situation in underground coal mines. Zhang et al. [17] used the RPE scale, the Stanford Sleepiness Scale, the digital write-off experiment, and the bright spot scintillator to measure fatigue before and after the Air Force radar squad. The experimental results showed that the RPE scores of the alert group and the navigation group increased substantially. The degree of fatigue is between "relatively light" and "a bit heavier." The error rate of the cancellation experiment in the alert group is considerably higher than that in the navigation group. Chen et al. [18] summarized the commonly used fatigue measurement methods from subjective and objective aspects and analyzed the advantages and disadvantages of various measurement methods and their applicable groups. Guo [19] et al. used BIOPAC MP150 physiological recorder and RPE scale to record the ECG, surface EMG, and fatigue data of subjects. The experimental results revealed that the heart rate shows an increasing trend in the early operation and then stabilizes. Heart rate variability (HRV) increases as a whole and increases with the increase of workload. The feeling of fatigue has a positive linear relationship with working time. Ye et al. [20] believed that a model could be built to calculate working time by oxygen uptake and heart rate, but this model could only calculate the maximum working time of the human body under a given task amount and could not describe the fatigue state of the human body in real-time. Hsu et al. [21] analyzed the causes of work fatigue of the human body, including fast working pace, low working motivation, high working pressure, long working hours, and poor working environment.

To sum up, from the point of view of research, previous studies on personnel reliability from the behavioral perspective mostly adopt relevant mathematical model analysis, which makes better interpreting the complex nonlinear relationship and coupling effect among various influencing factors of underground coal mine safety system difficult. Second, from the perspective of sociology, epidemiology, and occupational disease prevention, the results are mostly the pathogenesis that leads to the decline of body function or damage, but no reason, effective solutions are provided.

Therefore, considering the existing research deficiencies and combined with the realistic characteristics of human factor engineering and the working environment of fully mechanized mining face, relevant experiments are designed according to the knowledge of safety engineering, environmental science, physiology, and behavior. By collecting the values of physiological indicators and then using the grey prediction principle to simulate the curve, the relationship between the physiological indicators of the pumping station driver and time is obtained, and the safe working hours of the work type are calculated. It provides a certain reference for reducing the physical and mental harm of noise, improving the reliability of human behavior, reducing human errors, and ensuring safe production.

The remaining part of this study is organized as follows: Section 3 describes the research methods and the modeling of the grey prediction model. Section 4 presents the physiological index data collection, measurement, types of underground pumping station drivers in coal mines, and the simulation analysis of physiological index changes with working hours. Section 5 summarizes the study and provides relevant conclusions.

3. Methodology

Using the grey prediction principle to simulate the collected physiological index values, the relationship between the physiological index of the pumping station driver and time was obtained, and the safe working hours of this kind of work were calculated.

Grey models are strictly theoretical, and their largest advantage is practicality. Their prediction results, which are not only applicable to the prediction of large data volume but also accurate when the data volume is relatively small (>3), are relatively stable. Among many grey models, the GM (1,1) is the most common one in the grey system. When GM (1,1) is used to realize the premeasured energy. The basic step is as follows: The original data column is set as $x^{(0)} = \left(x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)\right)$, where n is the number of data.

The GM (1,1) model is established according to $x^{(0)}$ data column.

The original data are accumulated to weaken the volatility and the randomness of the random sequence and obtain the new data sequence:

$$x^{(1)} = \left(x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(n)\right) \tag{1}$$

where data in $x^{(1)}(t)$ represent the accumulation of the data corresponding to several previous items.

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), \qquad k = i, 2, \cdots n \tag{2}$$

The following first-order linear differential equation for $x^{(1)}(t)$ is established, namely, the GM (1,1) model.

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = u \tag{3}$$

where a and u of undetermined coefficients are called development coefficient and grey action, respectively, the effective range in a (-2,2), and *a*, *u* matrix of the grey parameters consisting of $\hat{a}=\begin{pmatrix} a \\ u \end{pmatrix}$. Therefore, only parameters *a* and *u* can obtain $x^{(1)}(t)$ then prediction $x^{(0)}$ value.

The accumulated generated data are used to generate *B* and constant term vector *Yn*.

$$B=\begin{bmatrix} -\frac{1}{2}(X^{(1)}(1)+X^{(1)}(2)) & 1 \\ -\frac{1}{2}(X^{(1)}(2)+X^{(1)}(3)) & 1 \\ \cdots & \\ -\frac{1}{2}(X^{(1)}(n\text{-}1)+X^{(1)}(\text{n})) & 1 \end{bmatrix} \quad (4)$$

The least-square method is used to solve the grey parameter $\hat{a}$, then

$$\hat{a}=(B^T B)^{-1} B^T Y_n \quad (5)$$

Substituting grey parameter $\hat{a}$ into $\frac{dx^{(1)}}{dt}+ax^{(1)}=u$ and solving for it obtains

$$\hat{X}^{(1)}(t+1)=(X^{(0)}(1)-\frac{u}{a})e^{-at}+\frac{u}{a} \quad (6)$$

$$Yn=\begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix} \quad (7)$$

$\hat{a}$ is an approximate value obtained by the least square method; thus, $\hat{X}^{(1)}(t+1)$ is an approximate expression. To distinguish it from the original sequence $\hat{x}^{(1)}(t+1)$, it is recorded as $\hat{X}^{(1)}(t+1)$. In the formula, *t* is a time series, which can be a year, quarter, or month.

Function expressions $\hat{X}^{(1)}(t+1)$ and $\hat{X}^{(1)}(t)$ are discretized, the difference between them is determined to restore sequence $x^{(0)}$, and the approximate data sequence $\hat{X}^{(0)}(t+1)$ is obtained as follows:

$$\hat{X}^{(0)}(t+1)=\hat{X}^{(1)}(t+1)-\hat{X}^{(1)}(t) \quad (8)$$

To test the established grey model, the steps are as follows:

Residual $e^{(0)}(t)$ and relative error $q^{(0)}(t)$ between $x^{(0)}(t)$ and $\hat{x}^{(0)}(t)$ are calculated:

$$e^{(0)}(t)=x^{(0)}(t)-\hat{x}^{(0)}(t) \quad (9)$$

$$q^{(0)}(t)=e^{(0)}(t)/x^{(0)}(t) \quad (10)$$

The model is used to make predictions:

$$\hat{X}^{(0)}=\left\{\hat{X}^{(0)}(1),\hat{X}^{(0)}(2),\cdots,\hat{X}^{(0)}(n)\right\} \quad (11)$$

The accuracy test is modeled, and the model is used for forecasting.

To analyze the reliability of the model, its accuracy must be checked. The posterior error test is the main method of the precision test at present, that is, deviation s_1 of the observation data is first calculated:

$$s_1^2=\sum_{t=1}^{m}\left(x^{(0)}(t)-\overline{x}^{(0)}(t)\right)^2 \quad (12)$$

Residual deviation s_2 is

$$s_2^2=\frac{1}{m-1}\sum_{t=1}^{m-1}\left(\varepsilon^{(0)}(t)-\overline{\varepsilon}^{(0)}(t)\right)^2 \quad (13)$$

Then, the posterior ratio is calculated:

$$c=s_1/s_2 \quad (14)$$

Small error probability is

$$p=\left\{\left|\varepsilon^{(0)}(t)-\overline{\varepsilon}^{(0)}(t)\right|<0.6745s_1\right\} \quad (15)$$

The model is diagnosed according to posterior ratio c and small error probability *p*. When posterior ratio $c<0.35$ and probability of small error $p>0.95$, the model can be considered reliable and used for prediction. At this point, the system behavior can be predicted according to the model.

The above steps are the whole analysis of modeling and prediction. When the residual error of the established model is large and the accuracy is less than ideal, the residual error GM (1,1) model should be modeled and analyzed to modify the prediction model and improve prediction accuracy.

4. Results Analysis and Discussion

4.1 Selection of physiological indexes

The underground working environment of coal mine is harsh, and various environmental factors are complex. This study selects the site environment of a mining surface pumping station of a mine under a group in Henan Province of China as the research background. To ensure the reliability of physiological data, the physiological sensitive indexes of heart rate, systolic blood pressure, and diastolic blood pressure measured in the field by the drivers and operators of pumping stations as the research subjects [16] are selected to provide a basis for quantitatively obtaining the safe working hours.

Blood pressure data were collected using the Yuyue brand mercury sphygmomanometer, and Yuyue brand electronic sphygmomanometer was used for comparison. When measuring heart rate, a Sassoon mechanical stopwatch was used to record the time. Participants were members of the same day's team of two o'clock in the afternoon. The pumping station drivers had no cardiovascular diseases, had no unhealthy habits, and were tested and confirmed to be in good health. They all volunteered to participate in the test and actively cooperated with the test subjects.

4.2 Determination of determination scheme

To calculate the safe working hours of the operators quantitatively and comprehensively, physiological indicators of the four-time node were collected as follows: when the operator just arrived at the working face, working for 2 h, working for 4h, and working for 6 h. The physiological index values of four-time nodes of 45 random samples were monitored and averaged for calculation. According to the principle of the GM (1,1) model above, mathematical software MATLAB was used to simulate and analyze the three physiological indexes of systolic blood pressure, diastolic blood pressure, and heart rate that changed substantially.

4.3 Simulation analysis of changes of physiological indexes of systolic blood pressure with working time

By taking average systolic blood pressure at four times nodes as the actual value and using the (1,1) GM model compiled by the MATLAB program in the appendix, this work inferred that the systolic blood pressure of the pumping station driver first drops and then rises by analyzing the curve simulation formula trend. Then, the pumping station driver will have an adaptation at the beginning of work; hence, systolic blood pressure drops. With the increase of time, the operator begins to become fatigued, and physiological indicators begin to rise slowly.

To work safely and efficiently, human physiological indicators need to be in an appropriate range. According to the grey prediction model and sensitive physiological indicators, the safe working hours of workers were calculated. After considering relevant information, the warning range of systolic blood pressure was determined: systolic blood pressure ≥140 mmHg. According to this range, the grey forecast model GM (1,1) was used to calculate the safe working hours of workers as 5.7959 h. The changes of pumping station drivers' physiological indicators over time are shown in Figure 1.

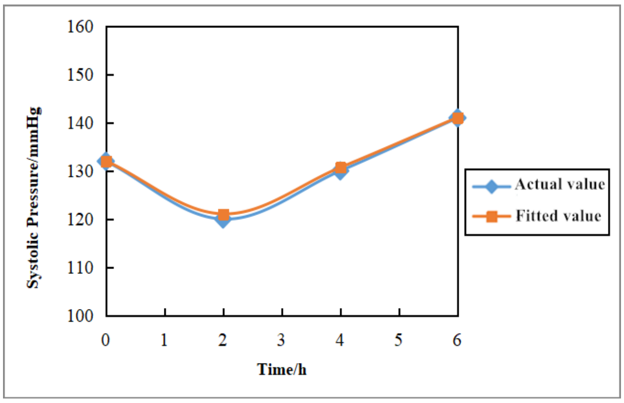

Fig.1. Safe working hours of systolic pressure

4.4 Simulation analysis of the changes of diastolic blood pressure physiological indexes with working time

The average diastolic blood pressure at four times nodes was taken as the actual value, and the GM (1,1) model of the MATLAB program was used to analyze and infer that the diastolic blood pressure of the operator decreases first and then increases. The staff has an adaptation at the beginning of work; thus, diastolic blood pressure drops. With the increase of time, the staff becomes tired, and diastolic blood pressure starts to rise slowly.

According to the grey prediction model and sensitive physiological indicators, the safe working hours of workers were calculated. After considering relevant information, the warning range of diastolic blood pressure was determined: diastolic blood pressure ≥90 mmHg. According to this range, the grey prediction model GM (1,1) was used to calculate the safe working hours of the pumping station driver as 8.25488 h. The changes of the pumping station driver's physiological indicators over time are shown in Figure 2.

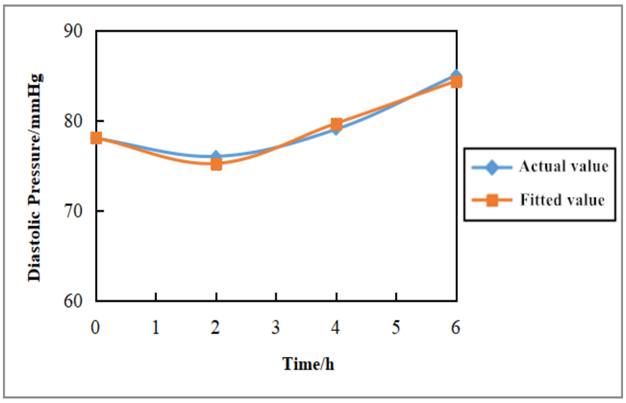

Fig.2. Safe working hours of diastolic pressure

4.5 Simulation analysis of heart rate changes with working time

Taking the obtained average heart rate of the four-time nodes as the actual value, using the GM (1,1) model of the MATLAB program, the analysis revealed that the staff's heart rate rises slowly in the early stage and finally stabilizes.

The safe working hours were calculated according to the grey prediction model and sensitive physiological indicators. After considering relevant information, the heart rate warning range was determined: heart rate ≥95 bpm. According to this range, the grey prediction model GM (1,1) was used to calculate the safe working hours of the pumping station driver as 15.28125 h. The changes of the pumping station driver's physiological indicators over time are shown in Figure 3.

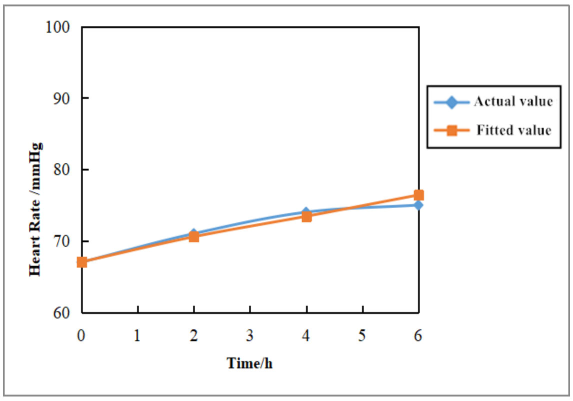

Fig.3. Safe working hours of heart rate

4.6 Comparative analysis of measured data with simulation results

The simulation analysis results of the three physiological indicators were integrated to conduct in-depth analysis and research on the overall situation. The specific conditions are shown in Table 1.

According to the fitting curve in Table 1, the value of physiological indicators at the one-time point in the future was predicted. Analyzing the entire curve of the fitting point and the prediction point revealed that various physiological indicators show a slow change trend over time. In the working environment, the workers in the fully mechanized mining face are mentally stressed and have physiological reactions, and the relevant indicators have changed.

Table 1. The forecast result of the physiological indexes by the grey forecast model

Physiological index	Maximum relative error	Posterior ratio *c*	Probability of small error *p*	Model evaluation
Pumping station driver's systolic blood pressure	0.90%	0.058949	1	reliable
Pumping station driver's diastolic blood pressure	1.03%	0.172736	1	reliable
Pumping station driver's heart rate	1.73%	0.144126	1	reliable

The grey dynamic model was used to analyze the change law of the subjects' various physiological indicators from the beginning to the end of the work. First, the original physiological index data were curve fitted, the curve-fitting equation was obtained, and then the physiological index data at the future time point was predicted through the equation. Based on the analysis of the fitting equation, a possible inference is that except for the heart rate index, all physiological indexes show a trend of the first decline and then rise over time. This finding shows that in the working process of the fully mechanized mining face, the operators have an adaption at the beginning of work, and the values of related indicators begin to decrease slowly. With the lengthening of working hours, the degree of physical fatigue of the workers gradually increases, their spirits tend to be tense, and the values of related physiological indicators gradually increase.

Table 2. Safe working hours

Physiological index	Threshold value	Safe working hours (h)
Systolic blood pressure	140 mmHg	5.7959
Diastolic blood pressure	90 mmHg	8.25488
Heart rate	95 bpm	15.28125

Table 2 shows that the working environment of comprehensive mining affects the safe working hours of operators. Different types of work and various physiological indicators correspond to diverse safe working hours. The safe working hours corresponding to heart rate is the longest, reaching 15.28125h, which shows that the working time of workers in a noisy environment has a minimal effect on heart rate. By contrast, the safe working hours corresponding to systolic blood pressure is only 5.7959h, which is the minimum value of the safe working hours corresponding to the three physiological indicators. When the working time of the operators in the underground fully mechanized mining face exceeds approximately 6 h, the systolic blood pressure of the operators will be higher than 140 mmHg. According to the World Health Organization, adult systolic blood pressure ≥140 mmHg can be diagnosed as hypertension. Here, when an operator in a fully mechanized underground mining face continues to work for more than 6 h, his systolic blood pressure level will be higher than 140 mmHg, that is, he will be in a state of hypertension. Afterward, if he continues to work, his systolic blood pressure level will be further improved. If this situation persists for a long time, it will have many adverse effects.

5. Conclusion

"Man-Machine-Environment" system engineering is the key content of coal mine safety production. Aiming at the effect of complex underground conditions on pumping station drivers and combining human factor engineering and the realistic characteristics of fully mechanized mining faces, related experiments were designed based on knowledge of safety engineering, environmental science, physiology, and behavior using the grey prediction model GM (1,1). The safe working hours of pumping station drivers were quantitatively studied, and the following conclusions are obtained:

(1) By monitoring, collecting and analyzing multiple physiological indicators of coal mine workers, the safe working time thresholds for pump stations drivers in fully mechanized coal mining face under different physiological indicators are scientifically obtained.

(2) The driver of the pumping station of the fully mechanized mining face has been in a state of higher-than-normal level of systolic pressure for a long time, which may cause damage to his physical health, negatively affect his working state, work quality and efficiency, and even cause unsafe behaviors of operators, which will lead to coal mine accidents.

(3) From the perspective of unsafe behavior control, the maximum safe working time for underground workers in coal mines is predicted. Based on the principle of triggering the minimum value of physiological index thresholds, 5.7h is selected as the reasonable safe working hours of the pumping station driver at the fully mechanized mining face. In actual production operations of fully mechanized coal mining faces in underground coal mines, reasonably arranging coal mine safety production operation systems based on the actual conditions of the coal mine and in combination with safe working hours is advisable.

The results presented in this study are based on the physiological index data and the grey prediction model GM (1,1) to determine the safe working hour model of pumping station drivers in the complex environment of underground mines, which provides certain theoretical support for the formulation of safe working hours for underground coal mine workers. However, the human-environment relationship in the complex underground environment still needs further research.

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References

1. Zhang, J. S., Fu, J., Hao, H. Y. "Root causes of coal mine accidents: Characteristics of safety culture deficiencies based on accident statistics". *Process Safety and Environmental Protection*, 4(136), 2020, pp.78-91.
2. Bošnjaković, M., Tadijanović, V. "Environment impact of a concentrated solar power plant". *Tehnički Glasnik*, 13(1), 2019, pp.68-74.
3. Urrutia, A. K., Stendorf, S. S., Molina, C. P. "Smart Zero Carbon City: key factors to-wards smart urban decarbonization". *Dyna*, 94(6), 2019, pp.676-683.
4. Wu, G., Gao, J. L., Zhi, G. H. "The influence of underground environmental factors on human error". *Coal Engineering*, (9), 2005, pp.40-41.
5. Jing, G. X., Li, C. Q., Peng, X. S. "Correlation analysis of the controversial environmental factors and human casualty cases in coalmine stopes". *Journal of Safety and Environment*, 12(1), 2012, pp.238-240.
6. Solonenko, I. "The equipment for determining the impact of traffic environment on road pavement". *Tehnički Glasnik*, 13(2), 2019, pp.149-153.
7. Fugas, C. S., Silva, S. A., Melia, J. L. "Another look at safety climate and safety behavior: Deepening the cognitive and social mediator mechanisms". *Accident Analysis & Prevention*, 45(7), 2012, pp.468-477.
8. Gun, R. T., Budd, G. M. "Effects of thermal, personal and behavioral factors on the physiological strain, thermal comfort and productivity of Australian shearers in hot weather". *Ergonomics*, 38(7), 1995, pp.1368-1384.
9. Feng, S. H. "The Qualitative and Quantitative Analysis of the Human Reliability in the Coalmine Production". *Journal of Liaoning Technical University (Natural Science)*, (4), 2000, pp.445-448.
10. He, X. H., Gao, J., "Comparison of Human Reliability Analysis Methods". *Nuelear Power Engineering*, (6), 2005, pp.627-630.
11. Chen, J., Cao, Q. G. "Prediction and evaluation of human error in coal production". *Mining Safety and Environmental Protection*, (01), 2007, pp.78-81.
12. Wang, D., Liu, L., He, H. B. "Improvement and application of human reliability analysis methods in coal mining production". *Journal of Inner Mongolia University (Philosophy and Social Sciences)*, 45(04), 2013, pp.60-65.
13. Massimo, B. "Assessment of human reliability factors: A fuzzy cognitive maps approach". *International Journal of Industrial Ergonomics*, 37(5), 2007, pp.405-413.
14. Groth, K. M., Mosleh, A. "A data-informed PIF hierarchy for model-based Human Reliability Analysis". *Reliability Engineering & System Safety*, (108), 2012, pp.154-174.
15. Podofillini, L., Dang, V. N. "A Bayesian approach to treat expert-elicited probabilities in human reliability analysis model construction". *Reliability Engineering & System Safety*, 117, 2013, pp.52-64.
16. Dong, J. L., Li, P., Ma, C. G., "Study on the monitoring of fatigue operation in coal mine based on EEG". *China Science and Technology Information*, 13(16), (2014), 82-83.
17. Zhang, Q. J., Yang, C. L., Ge, H. "Evaluation of workload in air force radar soldiers", *Journal of Preventive Medicine of Chinese People's Liberation Army*, 33(5), 2015, pp.506-508.
18. Chen, J. W., Bi, C. B., Liao, H. J. "A comparative study on measurement methods of work fatigue". *Journal of Safety Science and Technology*, 7(5), 2011, pp.63-66.
19. Guo, F., Lv W., Li M. M. "Analysis of manual materials handling fatigue based on SEMG and ECG". *Chinese Journal of Ergonomics*, 24(1), 2018, pp.1-6.
20. Ye, T., Pan, X. "A convenient prediction model for complete recovery time after exhaustion in high-intensity work". *Ergonomics*, 58(8), (2015), pp. 1433-1444.
21. Hsu, D. J., Sun, Y. M., Chuang, K. H., Juang, Y. J., Chang, F. L. "Effect of elevation change on work fatigue and physiological symptoms for high-rise building construction workers". *Safety Science*, 46(5), (2008), pp. 833-843.