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A risk control method based on two-factor theory

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Abstract: Risk management as an effective means to prevent accidents has been widely applied in coal mines in China. Risk control is the final stay point of risk management. As the key part to reduce risk it plays an important role in improving safety production level of coal mine. Because of lacking theory supports, it is difficult for the current methods to control risks systematically and specifically. Based on two-factor theories and the organizational structure, this paper will present a risk control method through analysis of physical condition failures and human errors.

Keywords: Two-Factor Theory, Risk Control, Physical Condition Failure, Human Error

1. Introduction

Our coal mine safety has a grim situation due to its complicated technological process, severe and changeable operating environment and the low awareness level of the workers (Zhang & Yan, 2011). Risk control as the final stay point of risk management plays an important role in eliminating hazards and reducing risks.

With the prevalence of risk management, a variety of hazard identification cards have been widely applied. But a deep-seated mechanism study of hazard causations was lacked (Cao & Wang, 2011). Therefore, the existing risk control was empty, vague and separated from practice. To a certain extent, the identified hazards are unable to be exactly eliminated. Round and round, the risk management is top-heavy, so accident prevention is like a blank check, no practical effectiveness is gained.

From flooding to explosive agents and the risk of asphyxia, miners are

exposed to some of the most hostile working conditions of any occupation. Due to the complicated production process and the harsh production conditions in coal mines, the problem of safety production in coal mine is more significant, complicated and difficult to solve compared with any other industry. With the growing complexity of systems, working conditions have become more difficult to understand and predict how they interact together. Therefore, more attention should be paid to the control of the physical condition failures.

Nevertheless, the majority of accidents cannot be solely attributed to adverse working conditions. For instance, a study by the US Bureau of Mines found that nearly 85% of all mining accidents identified human error as a causal factor. Clearly, if safety is to be improved, it is also vital to control human errors.

Based on two-factor theories, this paper will develop a scientific and reasonable risk control method targeting on physical condition failure and human error.

2. Analysis of Two-factor Theory

The unsafe acts of workers and the unsafe conditions in workplace which one plays a dominant role in accidents is a controversial issue among scholars. Therefore, different accident-causing theories were proposed respectively targeting on human errors and physical condition failures.

2.1. Theories Based on Human Error

From the early accident proneness theory proposed by M.Greenwood and H.H.Woods in 1919 to the later domino theory proposed by H.W.Heinrich in 1980, human error was regarded as a main causation of accidents. Even though some the accidents were caused by unsafe conditions, these unsafe conditions were taken for the results of human errors (Heinrich**,** 1980).

Focused on human error, some human error models were respectively proposed by Goller in 1969, Surry in 1969 and Wigglesworth in 1972. These models not only highlight the effects of human error, but also explain why workers make mistakes. Based on the models above, a human error model targeting on gold mine was established by Lawrence in 1974. All of these models defined human error as inappropriate and wrong responses to stimulations.

Reason explained why workers make mistakes through another way. Errors are seen to emerge from psychological factors in individuals such as aberrant mental processes, including forgetfulness, inattention, poor motivation, carelessness, negligence, and recklessness (Reason, 2000).This kind of models

include Norman's schema activation error model, Reason's Generic Error Modeling System and Rasmussen's model of human malfunction. These models typically attempt to identify the nature and frequency of the errors made by workers within complex systems, the ultimate aim being to propose operator-focused strategies and countermeasures designed to reduce variability in human behavior.

All the human error based theories are focused specifically upon human behavior, rather than the inadequate physical conditions.

2.2. Theories Based on Physical Condition Failure

With the growing complexity of systems, it is aware that in addition to unsafe acts, there must be certain unsafe conditions when accident happened. R.Skiba thought that workers and mechanical equipments are two important factors in accidents. For some industries, unsafe conditions of mechanical equipments play a more important role. Accidents can be greatly reduced through improving the safety and reliability of system.

Gibson and Haddon et al. proposed a theory of causation regarding the unplanned release of energy as a cause. The theory clarified the physical nature of accidents and pointed out that to prevent injuries is to prevent unplanned release of energy and to prevent human exposure to energy.

Based on Haddon's theory, Michael Zabetakis proposed a new domino theory of accident causation (Heinrich**,** 1980). This theory treated unplanned release of energy or hazardous substance as a direct cause of accidents. Then unsafe acts and unsafe conditions were regarded as the direct causes of the release of energy. Mechanical equipments are the carriers of energy. So the probability of accidents can be reduced through improving equipments and technologies.

In the 1970s, the labor bureau of Japan came up with the "Orbit Intersecting Theory" after a investigation (Sui, Chen, & Sui, 2005). Then a catastrophe model for accident-causing was proposed by Xinming Qian in 1995 (Qian & Chen, 1995). These two theories both argued that accidents were attributed to unsafe acts of humans and the unsafe physical conditions.

Whether the human factor or the physical condition factor is in a safe state, by improving the condition of either one factor, the safety production level and labor productivity can be raised by a big margin (Qian & Chen, 1995).

Whether the theories arguing human error as a cause or the theories arguing physical condition failure as a cause, leaving aside who playing a dominant role in accident, we can be sure that both of the two factors have certain influences on accidents. Neither of they should be ignored. We should start from both sides,

rather than focusing on a certain factor solely.

3. Analysis and Control of Physical Conditions Failure in Coal Mine

The probability of physical condition failures in coal mine is far higher than other industries due to its complicated technological process, adverse and changeable operating environment and various mechanical equipments.

3.1. Analysis of Physical Conditions Failures

In man-machine system, the mechanical equipments, substance, production objects and other factors of production are collectively referred to as physical conditions (Li, Fu, & Lu, 2005). According to their different functions in the man-machine operating system, these factors are divided into four types: structures, mechanical equipments, substances and tools. The event chain of these physical conditions is design→manufacture→maintenance→application →abandon (Sui, Chen, & Sui, 2005).

Combining physical conditions and life-cycle together we get a two-dimensional diagram, as is shown in Figure 1. Making sure that each intersection in Figure1 is safe, the physical conditions failures can be avoided.

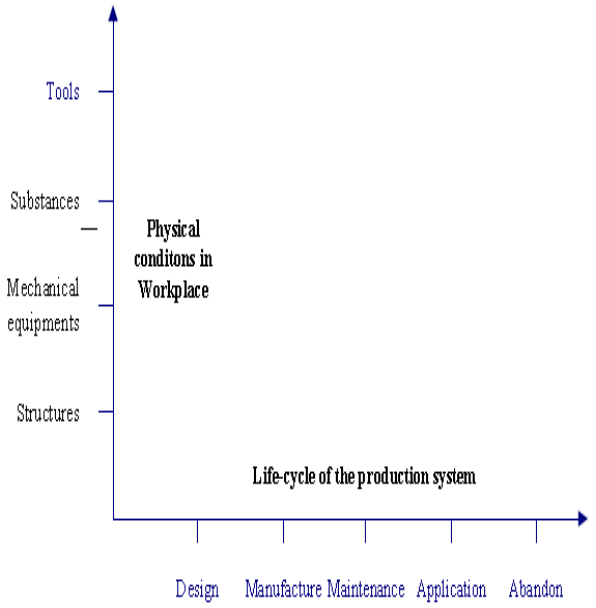

Fig.1: Two-dimensional diagram of the life-cycle of the physical conditions.

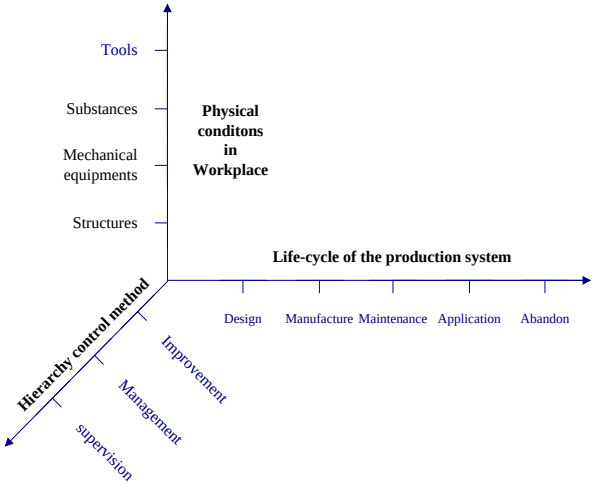

Fig.2: Three-dimensional diagram of physical conditions risk control.

3.2. Control methods of Physical Conditions Failures

In general, enterprises are consisted of decision layer, management layer and operating layer. The employees of different layers have different ways to control the failures due to their different functions and authorities. Table 1 shows a hierarchy risk control model of physical condition failures based on the above organizational structure.

Table 1: A hierarchy risk control model of physical condition failures

Layers	**Control methods**	**Control objectives**	**Detailed ways**
Decision Layer	improvement	Essential safety	Decision makers should try to eliminate the hazards in workplace, such as replacing the toxic and hazardous material, designing and purchasing the equipments of high reliability.
Management Layer	Management	Reducing risk	If some hazards cannot be eliminated, then managers need to reduce the risk through prevention, reduction and isolation measures.
Operating Layer	supervision	Controlling residual risk	Some residual risks may still exist in workplace after the above controlling. Then operators are required to monitor, supervise and communicate these risks constantly

Based on the analysis above, a three-dimensional diagram of physical conditions risk control was developed shown in Figure 2. Not only the control objectives can be clear, the causation of the failures can also be found through this three-dimensional control method. Then the risk control will not be that empty, vague and separated from practice.

4. Analysis and Control of Human Error in Coal Mine

Physical factors are the prerequisites to keeping safe. And human factors are internal factors (Li, Fu, & Lu, 2005). Controlling human errors effectively is a significant way to prevent accidents.

4.1. Analysis of Human Errors

The human factors in the coal mines of China more commonly refer to the so-called "three violations". A survey was conducted among the front-line workers in a coal mine. Through the analysis of the questionnaires, it is found that 11% of the workers took violating actions because they do not know that the acts are violations of the relevant rules and regulations. So this kind of violations is named as "ignorant fearlessness". These workers are mainly new employees or transferees from other positions. Another 64% of the workers knew their behaviors were illegal, but in the past these behaviors had never lead to any accidents, so they took the violating actions fearlessly. So this kind of violations is named as "knowingly and willful". These workers are mostly older employees who have some experience. The rest 25% of the workers took the violating behaviors due to misjudgment and negligence. So this kind of violations is named as "misstep".

Unsafe actions are driven by the above three consciousnesses. Through a forum with workers, it is found that the negative consciousnesses generated due to capabilities, physical and emotional stimulations, such as lower technical level, fatigue, bad health condition, agitated mood and low spirit etc.

The mentioned fatigue, bad health condition and other factors are negative stimulations to the workers according to the Surry mode (Heinrich, 1980), the Ferrell theory (Heinrich, 1980) and the Petersen accident-incident causation model (Heinrich, 1980). Thus negative stimulations make the workers generate consciousnesses of leaving things to chances and the consciousnesses of trying facile ways and so on. Therefore, unsafe actions were taken.

In order to eliminate human errors, firstly, negative stimulations should be eliminated from root. Secondly, the way that these stimulations evolve into unsafe actions should be cut off, that is to transform the negative consciousness of workers.

4.2. Control Methods of Human Errors

During the daily safety inspections, the underlying factors are rarely corrected. A hierarchy control method which is similar to the controlling of physical

condition failures is developed, shown in Table 2. In this way, risk control will be done retroactively when something goes awry, rather than scratching the surface of a problem.

Table 2: A hierarchy risk control model of human errors.

Layers	**Control methods**	**Control objectives**	**Detailed ways**
Decision layer	Organization management	Avoiding negative stimulations	Constructing safety culture Arranging work rationally Clarifying safety responsibility granting safety rights
Management layer	Behavior management	Suppressing negative consciousnesses	Training and education Motivation mechanism Enacting reasonable safety rules and codes
Operating layer	Mandatory correction	Guarding against unsafe actions	Adequate supervision

5. Conclusion

Risk control plays an important role in the process of eliminating and reducing risk. To eliminate risks effectively, the ideas and objectives of risk control should be exactly clear. Under the guidance of two-factor theories, the following results were got targeting risk control in workplace.

(1) Physical condition factors in workplace and the life-cycle of production system were analyzed. Combining the two-dimensional diagram of life-cycle of the physical conditions with hierarchy risk control of failures, a three-dimensional diagram of physical conditions risk control was developed.

(2)Based on the Surry model, the Ferrell theory and the Petersen accident-incident causation model, the causation of human error in coal mine was analyzed. According to this causation, a hierarchy control method of human errors was developed.

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