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# The Coal Mine Accident Causation Model Based on the Hazard Theory

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## Abstract

On the basis of the summary of the existing research, first of all, the essential factors of coal mine accidents was differentiated and analyzed, and the technology equipment defects was believed to be the essential reasons that affect the coal mine safety. And then using the hazard theory the accident causation in coal mine production system has been divided, and it was believed that coal mine hazard sources consisted of inherent hazards, technology equipment defects and safety management misconducts. On this basis, the coal mine accident causation model on a combination of hazard theory and energy accidental releasing theory was established. Finally, this model was used to analyze the roof-fall accident of Baishui Coal Mine.

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*Keywords:* hazard theory; coal mine accidents; accident causation Model

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## 1. Introduction

The statistics of the State Administration of Work Safety of the 2009 and from January to June of 2010 showed that, in the context of the national safety situation improving continuously, the number of casualties in coal mine enterprises and death tolls also declined, but major and serious accidents still happened frequent, among which the number of serious casualties killed 3-9 people and death tolls even continued to rise. while " various measures has been actively taken and the safety production supervision

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and inspection has been strengthened", the safety situation in coal mine enterprises has not been effectively controlled, largely due to the lack of deep understanding of the mechanism of coal mine accidents and the law of development, and the failure of taking appropriate preventive measures. Therefore, the study of coal mine accident causation model has important significance on promoting coal mine enterprises safety production.

However, coal mine accident causation model can not simply copy some theories, but must be based on the characteristics of coal mine enterprises, in order to solve practical problems in coal mine safety. Meanwhile, only when the real cause of the frequent coal mine accidents are made clear will it be possible to solve the basic questions of coal mine safety. In this paper, first of all, the essential factors of coal mine accidents was differentiated and analyzed, and then, the accident causation in coal mine production system was analyzed using the hazard theory, and the coal mine accident causation model based on hazard theory was established, finally this model was used to analyze the coal mine typical accident.

## **2. Analysis of coal mine accident causation**

The coal industry is a high risk industry. Since there are many underground coal mining, compared with other industries (including non-coal mining) and enterprises, the coal mines have more disaster types, more wide distribution, more poor production environment and more dependence on technology and equipment, and are objectively more prone to major and serious casualty accidents.

### *2.1. The study of frequent coal mine accidents causation and preventive measures*

In China the fact of frequent occurring of coal mine accidents and the security situation being still not effectively controlled has attracted wide attention. Many scholars have studied and analyzed in various aspects of the reasons of frequent coal mine accidents, and the corresponding preventive measures have been put forward<sup>[1-3]</sup>. It can be expressed comprehensively as follows:

The main reasons for frequent coal mine accidents in our country, in addition to serious natural disasters, include the following: ① the problems in supervision and management: unreasonable coal industry management system; the difficulties in the implementation of enterprise's safety work responsibility system; the over-capacity production of some coal mines; the serious insufficient investment in safety; the inadequate punishment intensity and so on. ② the poor level of safety technological equipment: the poor technological equipment; the low level in mechanization; the safety monitoring and warning system being imperfect; the lack of technology personnel and so on. ③ the low quality of staff and workers: the lack of safety awareness; the problems of migrant workers and so on. ④ other problems: the problem of small coal mines; the community between bureaucrats and coal businessmen; the local protectionism.

The corresponding preventive measures include: ① the establishment of a sound safety-related laws and regulations, and the strengthening of law enforcement and supervision; to adjust the industrial structure and rationalize the relationship; to reify enterprise safety responsibility, and when problems arise, seriously punish those responsible. ② to strict entry criteria of coal mining enterprises, to raise the threshold of coal mining enterprises; to improve the treatment of technicians; to implement of the principle of "safety first, prevention first" and so on. ③ to implement the safety standardization; to enhance safety culture, to attach importance to safety education, to strictly implement the qualification training system; to strictly insist on the quality of staff and workers and so on. ④ to continue to close small coal mines that can not meet the conditions; to strengthen law enforcement and to crack down on the community between bureaucrats and coal businessmen and local protectionism.

2.2. Analysis of the essential factors

At present the management misconducts were classified as the essential reasons by most of the accident causation models of coal mine<sup>[1-3]</sup>, which emphasized that the accidents were caused by mismanagement. This was an inevitable conclusion using the classic accident causation theory. However, some scholars also pointed out that, according to the analysis of the statistics of coal mine accident data in China, the impact of technology and equipment level to safety condition of coal mine enterprise was greater than management<sup>[4,5]</sup>. In order to fundamentally solve the coal mine safety problem, it is necessary to further study the essential reasons of the frequent coal mine accidents.

2.2.1 Technology and equipment determine the basic safety level of coal mine enterprises

(1) The development of safety science shows that the safety production level of the enterprise depends on its level of technology equipment.

In safety engineering, the safety of the production conditions such as the machinery, equipment and physical environment, are called as intrinsic safety. In the intrinsic safety system, accidents do not happen even if there are human errors, because the accident conditions do not exist.

It is generally believed that human error rates are between 10<sup>-2</sup>-10<sup>-3</sup>, however the machine failure rates are between the 10<sup>-4</sup>-10<sup>-6</sup>, so it is thus clear that the human error rates are higher than the machine failure rates by 2-3 orders of magnitude. In case that the economic and technical conditions permit, the machinery should be used to take the place of human, as far as possible to realize intrinsic safety from a technical point. Therefore, among all the safety countermeasures of accident prevention and control, it should be considered firstly to achieve intrinsic safety of production processes and production conditions through safety technology countermeasures, followed by the safety management.

(2) The practice of domestic and international shows that the technology and equipment determine the basic safety level of coal mining enterprises.

Figure 1 shows the variation trends of the coal mining mechanization degrees and the mortality per million tons in China's state-owned key coal mines from 1990 to 2004, the two curves. Although the two curves fluctuate greatly, with the steady increase of mechanization degree, the mortality per million tons shows a obvious downward trend<sup>[4]</sup>. Some scholars have made multivariate statistics regressive analysis of the safety situation of the coal mining enterprises during the period<sup>[5]</sup>, the results also showed that the coal mining mechanization degree were the most significant indicators that affect the safety situation of coal mine enterprises in our country.

Figure 2 shows the variation trends of the coal mining mechanization degrees and the mortality per million tons in United States from 1986 to 1995. It can be seen, coal mining mechanization has a clear negative correlation with the mortality per million tons, that is, with the promotion of new technology and new equipment, the coal mine safety situation has improved markedly.

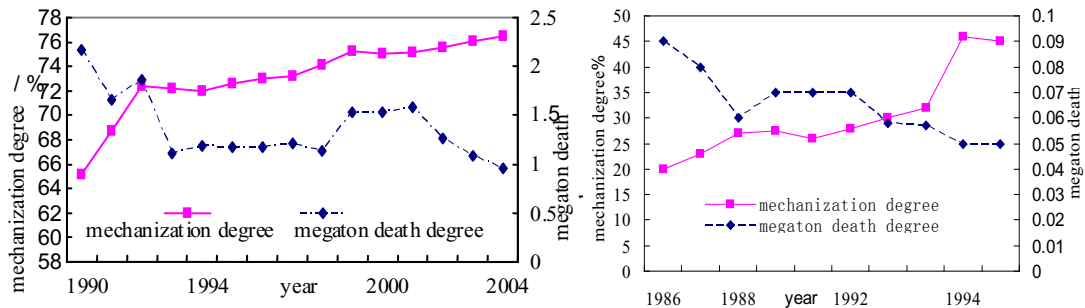


Fig.1 Mechanization degree and megaton death degree in China Fig.2 Mechanization degree and megaton death degree in USA

### 2.2.2 Safety management is the powerful compensation of inadequate technology equipment level

Safety management, in order to ensure achieving safety goals timely and effectively, is the work of planning, organization, coordination, inspection based on the forecasting and analysis, which is an effective means to prevent breakdowns and personnel errors.

Due to the influence of subjective and objective factors such as economic level, the intrinsic safety degrees that the coal mine enterprises in China can achieve are still very low. In this case, the safety management of coal mining enterprises is particularly important, and it is the underlying cause to determine the coal mine safety situation. However, through the relationship between the two it is easy to see, we can not ignore the improvements of safety technology and equipment. "Intrinsic safety" is the ideal, is the goal, is the effort and aim.

On the basis of the above, the author think these issues should be viewed comprehensively and scientifically based on the actual conditions of coal mine safety, in stead of one-sided emphasis on one aspect: First, from the long-term interests point of view, the development of technology and improvement the equipment level should be taken as the main direction for improving coal mine safety; Secondly, in the conditions of the existing technology and equipment level, the importance of safety management should be emphasized, especially inside the coal mine enterprises, the management failures should be devoutly believed to be the basic cause of coal mine accidents, and it is the important basis for achieving long-term stability of coal mine to improve and strengthen management.

### 2.3. *The analysis of coal mine accident causation model based on the hazard theory*

The hazard is the source of danger, or that, the hazard is the combination of the basic conditions and factors leading to hazard of events. In the national standard of "Specifications on Occupational Safety and Health Management System", the hazard is defined as the causes or state that may cause harm or illness, property loss, or work environment damage or the combination of all these circumstances.

Many scholars have done a lot of researches on the hazard classification and roles in causing the accident, among which the currently widely used are the Theory of Two Types of Hazards proposed by Professor Baozhi Chen<sup>[6]</sup> and the Theory of Three Types of Hazards proposed by Dr. Suicheng Tian<sup>[7]</sup>.

In order to avoid undue emphasis on safety management and ignorance of the roles of technology and equipment standards to coal mine safety, this paper has divided the accident causation factors of the coal mine enterprises using the hazard theory.

#### 2.3.1 The hazards of coal mine enterprises

Through analysis of coal production system, the hazards of coal mine enterprises can be divided into three categories:

(1) The inherent hazards: the energy or dangerous substances inherent in coal mine enterprises which may possibly release. It is generally believed that there are eight kinds of inherent hazards in coal mine enterprises: gas, fire disaster, coal dust, water, roof, blast, transportation and electric machine. Inherent hazards determine the objective risk in the system, and are the main influencing factor of the severity of the accident consequences.

(2) The technology and equipment defects: the dangers posed by existing inadequate safety technology and equipment level. This safety technology and equipment mainly include two aspects as safety protection and disaster mitigation system and monitoring and control early warning system. Safety technology equipment is a barrier set around the inherent hazards, the level of which determines the level of control and restrain ability of the enterprise to inherent hazards. Whether the state-owned large mines or the small local mines, the existing technology and equipment level is far from the essential safety, which results in the inadequacy and defects in control and constraint of the inherent hazards. In addition,

advanced monitoring and control technology can provide accurate early warning safety information and improve the accuracy of management decision-making, and even can achieve automatic control and has immunity against incorrect manipulation. On the contrary, inadequate or inaccurate safety information can lead to management misconducts, or increase the possibility of mismanagement to make decisions only based on historical experience.

(3) The safety management misconducts: poor organization and management, include the defects in the aspects such as safety administration department, safety production responsibility system, safety management rules and regulations, safety input, safety manager, etc. For example, the safe production responsibility system can not be implemented, the safety management institutions are not perfect, and the safety management regulations are imperfect.

2.3.2 The relationship of the three types of coal mine hazards

The Inherent hazard is the premise of energy leading to the incident, and the main body of destruction, which determines the objective hazard of the system; technology equipment defects determine the extent of possibility of transformation of the objective hazard into the real hazard, which have a great impact on the likelihood and severity of consequences of the accident, meanwhile the technology equipment defects can also produce safety error messages which will lead to mismanagement; safety management misconducts are the incentives leading to the accident, the specific forms of which are human error, material failure and adverse environment, and they can trigger technology and equipment defects, so that cause loss effective control of inherent hazard, and result in coal mine accidents.

3. The coal mine accident causation model based on the hazard theory

On the basis of the above analysis of coal mine enterprises hazards, and on a combination of energy accidental releasing theory, the coal mine accident causation model based on the hazard theory was established, as shown in Figure 3.

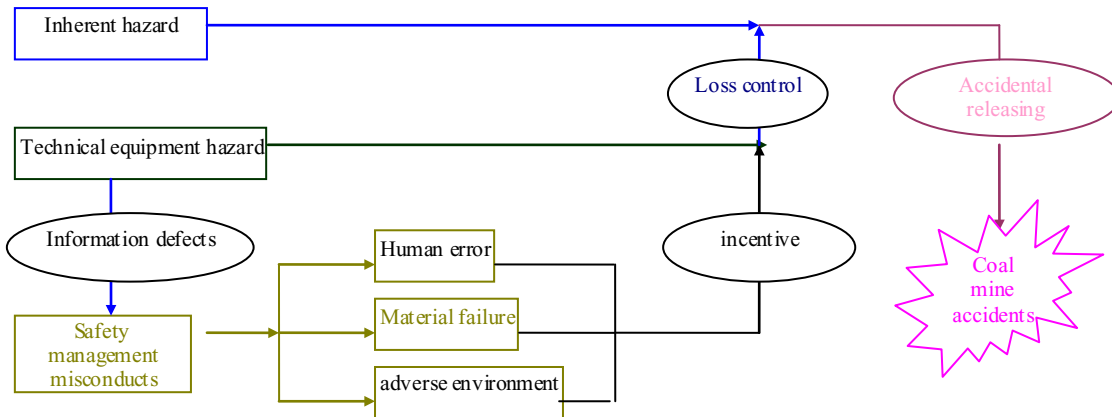


Figure 3 The coal mine accident causation model based on the hazard theory

4. Case Study coal mine accidents

At 16:00 on April 6th, 2005, a roof-fall accident occurred at empennage of No. 22514 Working Surface of the Baishui Coal Min of Pubai Mining Bureau of Shaanxi Province, one person died in the accident.

The accident history as follows: on April 6, the director of the reverse briefing stressed to the second advancing team of the morning shift on the pre-shift meeting that "to pay attention to safety in initial mining and discharging, and to ensure safety during production," and then the staff and workers entered the coal mine and started to work. Cui and two other comrades were assigned in the empennage section. At 13 o'clock all the main canopies moved. While moving the assistant canopies, Cui watched over the roof beside side wall of the empennage(vice beam), the other two comrades moved the assistant canopies from low to high beside the head unit. Around o'clock, when they were changing the sixth assistant canopies, the roof fell, and Cui failed to dodge and buried to death.

The following is the analysis of the accident using the accident causation model in this paper.

#### (1) Poor safety management

The poor field commencement management, poor sense of responsibility of managers, the failure of close safeguard of key areas, the failure of grasping the weak weaknesses; No organization of formal acceptance of work before commencement, and too eager to start production; Mine team management was lax and extensive, the commencement work arrangement was vague, general and aimless, which was the typical paying more attention to production and less attention on safety, and just going through the formality; the self-protection awareness and the ability of identifying hazard of the staff and workers is poor.

#### (2) The level of technology and equipment level is low

The once roof of the point of cutting was about 3.5 meters high and 2.5 meters long, when processing roof fall a scaffold of 18 layers was set, together with the inclination angle at this place was 15-16 degree, there was no purposeful safety technical measures on the roof control in initial mining and discharging; There was no bumpy surface between the slope supports and roof, and at the joint of the putlog hole and the roof no connection support and pergola six columns, which resulted in powerless support.

At the working face the rough roof support technology, poor equipments, and even the lack of monitoring and control system, so it is far from intrinsic safety and don't have the conditions for safe production.

#### (3) The energy release of inherent hazards

The roof separation of the upper roof (3.0 x 2.0 x 0.6), pushed over the support, led to roof fall, and caused the deaths of workers.

## 5. Conclusions

- The level of technology and equipment determine the basic safety standard of the coal mine enterprise, and safety management is a powerful compensation for the shortage of technology and equipment level;
- The hazards of coal mine enterprises can be divided into three categories as the inherent hazards (including 8 types such as roof, gas), technology equipment defects and safety management misconducts. Among them inherent hazard is the main body of damage, and determines the objective hazard of the system; the technology equipment defects determines the degree of possibility of objective hazard of the system into real hazard; Safety management misconducts are incentives, which can trigger technology equipment defects and cause accidents.
- The coal mine accident causation model was established on a combination of hazard theory and energy accidental releasing theory, and the accident of roof fall of the Baishui Coal Mine was analyzed successfully.

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