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Analysis of the Causative Mechanism of Coal Mine Safety Accidents Based on STAMP Model

Jie Dong*, Zixiang Gao, Tingting Liu, Xiangyang Ma, Huichao Liu, Sen Yang, Shanshan Cui

CSSC Systems Engineering Research Institute, Beijing, 100094, China
**Corresponding author*

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Abstract: With the development of mining methods and mining technology towards high efficiency and intensive production, the coal mine production system is becoming more and more complicated, and the frequent accidents make the coal mine safety problem particularly thorny. In order to be comprehensive and deeper understanding of coal mine safety accidents cause mechanism, this paper combined with the actual characteristics of coal mine safety production management, to build a model based on the STAMP model of coal mine safety accident cause and control problem, safety problem can be converted to applied to coal mine safety accident analysis, it is concluded that the coal mine accident cause analysis in detail. Finally, the comparison between the above cause model and the traditional cause model shows that the newly established STAMP model is helpful to clarify the accident occurrence mechanism and has a great role in guiding the investigation and safety management theory of coal mine accidents. It changes from passive control to active control and controls coal mine accidents to the best state.

1. Introduction

Over the years, our awareness of coal mine safety has been numb, and our investment in coal mine safety has been even less. However, in recent years, our awareness of safety has been awakened, and the state has implemented relevant policies and increased investment in coal mine safety[1]. However, coal mine accidents are still occurring, and the number of deaths is still high [2]. Obviously, coal mining enterprises and people have insufficient understanding of the cause mechanism of coal mine safety accidents[3], Lack of theoretical support and guidance, unable to find out the cause of the accident[4], so as to get updated and better methods to avoid losses, so unable to comprehensively and systematically analyze the accident [5], and has not achieved significant results in controlling the occurrence of coal mine safety accidents. In view of the above problems, combined with the STAMP model [6], this paper constructs a new model of coal mine safety accident causation and applies it to the accident analysis of coal mine safety[7], obtains a detailed analysis of coal mine accident causation, and then compares it with the traditional causation model, obtains the unique advantages of the new model, and puts forward relevant improvement measures to further develop the coal mine safety management.

2. Principle and Structure of STAMP

In system theory, emergent characteristics originate from the interaction between system components. Constraining the behavior of components and interactions between components is an effective method to control emergent characteristics. In this way, security becomes a control problem. Its goal is to control the behavior of the system by implementing security constraints in the design and operation process. In the whole framework, it is very necessary to understand the causes of accidents caused by ineffective control. To prevent accidents, it is necessary to shift the focus from the original failure prevention to a wide range of objectives, that is, to design and implement controls to enforce necessary constraints. The STAMP model is based on the above principles.

The STAMP model is divided into three parts: security constraints, hierarchical security control structure and process model. Safety constraints are the most basic concept in the STAMP (System Theoetic Accidental Modes and Process) theory[8]. STAMP theory believes that it is the failure to effectively implement safety constraints that will lead to accidents and losses. Safety constraints are divided into two categories, namely, the safety constraints of passive control and the safety constraints of active control. For today's complex systems, we first need to determine security constraints, and then design effective controls to ensure security constraints.

3. Cause Model of Coal Mine Safety Accidents Based on STAMP

The most basic concept in the STAMP model is not an event, but a security constraint. For the cause of the accident, the STAMP model considers that it is caused by insufficient control of the internal or external interference of the system, or the ineffective implementation of safety constraints during system development, design and operation. Figure 1 shows a basic process control loop based on STAMP hazard analysis. The controlled process is controlled by process input and external interference. The information output from the process may be input into other relevant process control loops[9].

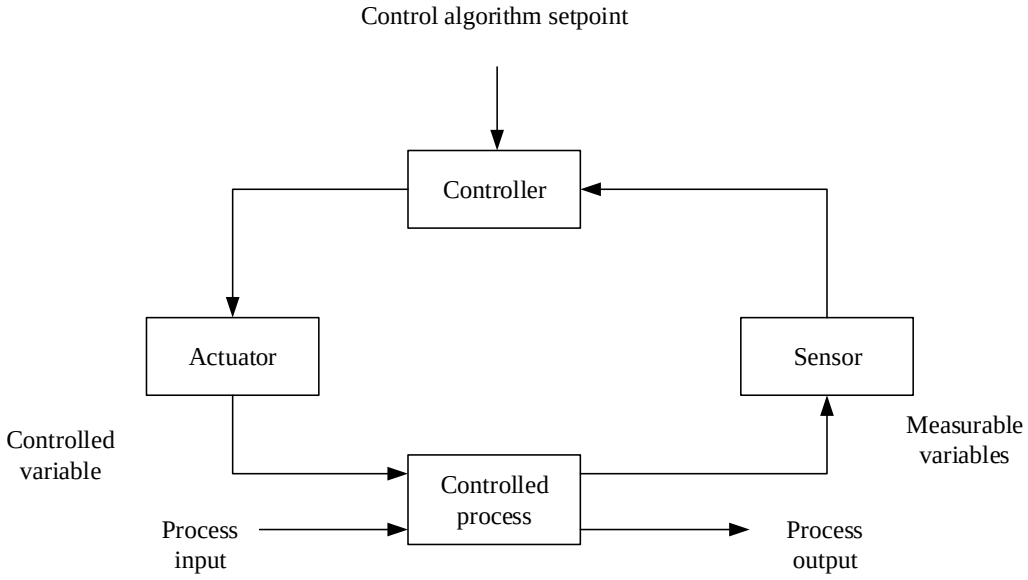

Figure 1: Standard Control Loop

Figure 2 describes the hierarchical control structure to ensure the safety production of China's coal mines, starting from the guidance route and laws provided by the State Council to the

electromechanical equipment in accidents. In Figure 2, the actuators from the mine employees to the workplace refer to the implementation of safety production laws and regulations, rules and regulations, standards, workplace ventilation and occupational health, and the sensors from the workplace to the mine employees refer to the temperature sensors and methane sensors in the workplace. The actuators from mine employees to electromechanical equipment refer to the implementation of operating procedures for electromechanical equipment and the management of electromechanical equipment, while the sensors from electromechanical equipment to mine employees refer to start stop sensors, portable methane detection alarms, etc. Actuators from the workplace to electromechanical equipment refer to requirements and restrictions on equipment design, while sensors from electromechanical equipment to the workplace refer to dust sensors.

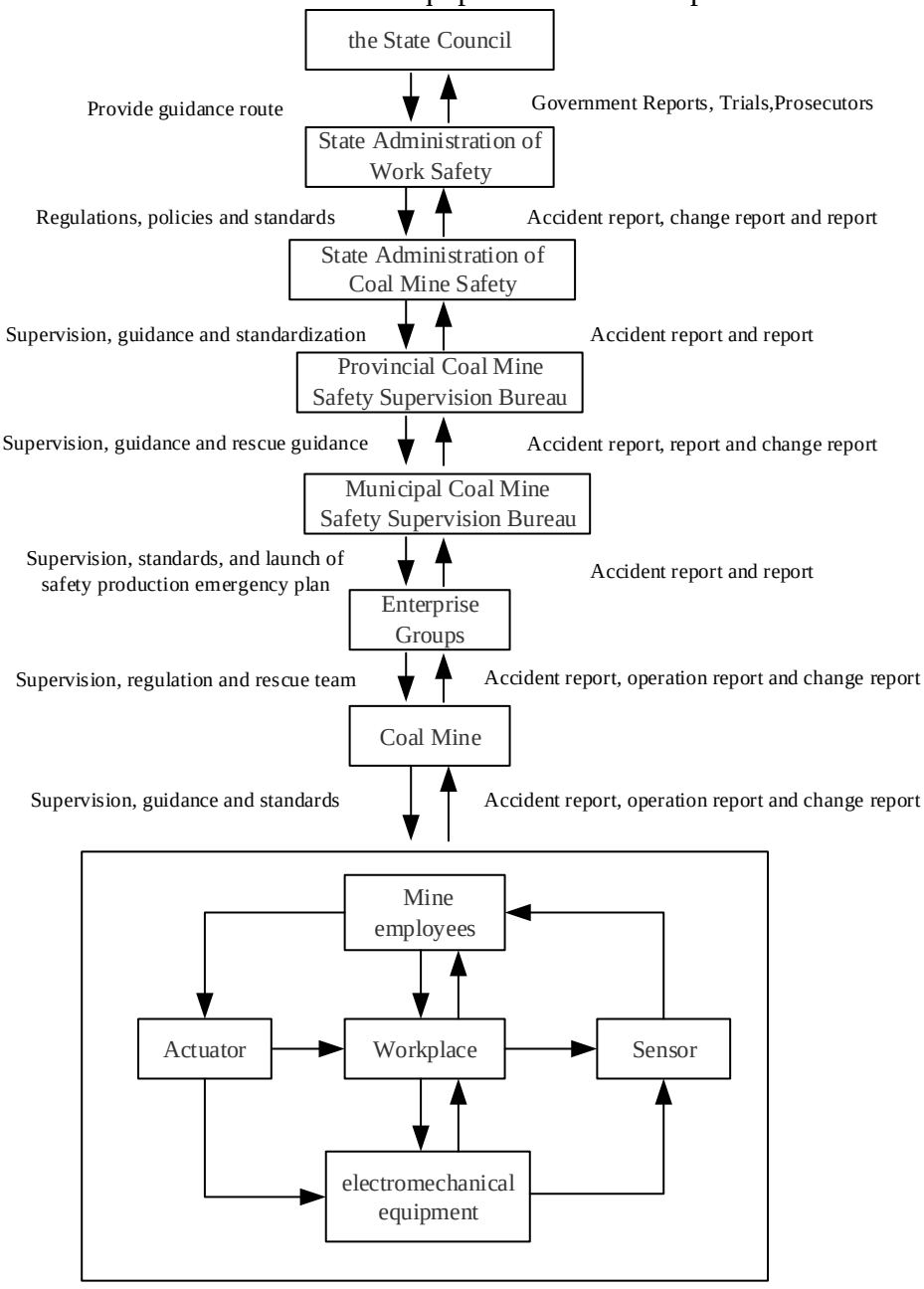

Figure 2: Hierarchical Control Structure of Coal Mine Safety Production

4. Cause Mechanism Analysis of Accident Cases Based on STAMP Model

The gas explosion accident occurred in Xiaojiawan Coal Mine of Zhengjin Industry and Trade Co., Ltd. in the west district of Panzhihua City, Sichuan Province on August 29, 2012. At 17:38, the gas volume exceeded the limit due to insufficient ventilation of the 10 # coal seam when it was lifted down the mountain. The workers produced electric sparks when operating the detonation loss device, which caused a particularly serious gas explosion accident, resulting in 48 deaths and 54 injuries, A huge direct economic loss of more than 40 million yuan.

According to the procedures of accident analysis based on STAMP model, the first step is to identify system hazards, and then implement safety constraints with appropriate system safety constraints and hierarchical safety control structures. The system hazard associated with the No.10 lifting downhill accident of Xiaojiawan Coal Mine is gas explosion, which requires the following system safety constraints to control:

(1) The mine workers who lift the No.10 coal seam downhill must cut off the ignition source through various ways.

(2) Mechanical and electrical equipment in the lifting and downhill operation site of Coal Seam 10 # must be kept in a relatively safe state.

(3) The gas concentration in illegal and irregular workplaces where the 10 # coal seam is lifted downhill is limited to the safe concentration (ensuring ventilation).

The cause analysis was made on the insufficient control displayed by each controller in the gas explosion accident in the lifting down hill of Coal Seam 10 #:

(1) Mine employees

The operation of mine workers is analyzed through STAMP model. First, because the mine workers do not have a strong sense of safety, they are not aware of the dangers and consequences when working in illegal and informal mining areas. Second, the mine staff's leadership awareness is not strong, and the mine head on duty did not guide the work in accordance with the regulations. Third, because they are busy with operation, the average working time of most mine employees in China is 200 hours per month. Some coal mines are super productive, even allowing the mining area staff to work more than 300 hours per month, which makes the workers very tired. The time of the accident is 17:38, which is a time point of human fatigue. It is very easy to slack off on the abnormalities of mechanical and electrical equipment and workplaces. Fourth, the lack of safety training for mine employees is very important for mine employees to understand the situation of the workplace. However, in the gas explosion accident of Xiaojiawan Coal Mine, the mine employees under the lift of Coal Seam 10 did not know that the gas in the workplace exceeded the limit and the electromechanical equipment failed to explode, and without knowing it, they operated the hoist signal device to generate electric sparks and detonate the gas.

(2) Zhengjin Industry and Trade Co., Ltd. and Xiaojiawan Coal Mine

When the workplace was abnormal, Xiaojiawan Coal Mine did not timely notify the relevant employees of the 10 # coal seam lifting downhill. According to the investigation, the causes of this fault are as follows:

1) Xiaojiawan Coal Mine dissembles the fact that it organizes production in violation of laws and regulations and evades the supervision of the government and relevant coal mine safety supervision departments.

2) The mine did not produce according to the designed production capacity of the mine, but produced beyond the capacity, resulting in an increase in the workload of mine employees. The number of mine employees was not properly controlled, resulting in overstaffing of the workplace and increased accident severity.

3) The control work of the mine staff management was not carried out effectively, resulting in

insufficient control over the regular inspection, maintenance and relevant safety measures of gas and relevant mechanical and electrical equipment in the workplace.

4) The feedback loop was paralyzed, and Xiaojiawan Coal Mine did not receive feedback from the mine employees, indicating that the gas in the workplace exceeded the limit and the electromechanical equipment failed to explode, let alone taking corresponding measures against it.

5) After the accident, the mine was informed, and the relevant person in charge and personnel were organized to enter the well for rescue and check the accident. However, he did not realize the seriousness of the situation, so he did not report to Zhengjin Industry and Trade Co., Ltd. in a timely manner, but only reported to him half an hour after the accident occurred, and called the rescue team to rescue him. The embodiment of this in the STAMP controller is that the time lag leads to insufficient feedback, which leads to insufficient control of control behavior.

(3) Sichuan Coal Mine Safety Supervision Bureau and Panzhihua Coal Mine Safety Supervision Bureau[10]

As a result, the supervision work of Panzhihua Coal Mine Safety Supervision Bureau was not carried out effectively, and the Xiaojiawan Coal Mine of Zhengjin Industry and Trade Co., Ltd. was able to produce illegally, causing accidents. In the control structure, the feedback channel is very important, but it is obvious that the feedback time lag of the coal mine leads to the difficulty of rescue work of Sichuan Coal Mine Safety Supervision Bureau and Panzhihua Coal Mine Safety Supervision Bureau, and the accident consequences are serious.

(4) State Administration of Coal Mine Safety, State Administration of Work Safety

The State Administration of Coal Mine Safety and the State Administration of Work Safety did not supervise the safety management of the provincial coal mine safety supervision bureau enough, and did not seriously supervise the problems of the Sichuan Coal Mine Safety Supervision Bureau. Due to poor management, the accident occurred.

5. Conclusion

The results show that the newly established STAMP model is helpful to clarify the mechanism of accidents, and plays a great role in guiding the investigation of coal mine accidents and the theory of safety management. It changes from passive control to active control, and controls coal mine accidents to the best state.

In order to prevent similar accidents from happening again, the following improvement measures can be referred to:

(1) Managers at all levels of the coal mine safety production system should strengthen personnel training and attach importance to the construction of coal mine safety culture. Each mine employee and manager should be more competent, more familiar with their work responsibilities and abide by the rules and regulations. For example, mine employees must abide by the corresponding operating procedures for mechanical and electrical equipment, and pay attention to the sensors and alarms in the workplace when working. In addition, employees in some departments should know not only their own responsibilities, but also the responsibilities of other departments. This will help to solve some problems related to many sectors. For example, when gas accumulates in the mine, if the mine practitioners know more about the responsibilities of other relevant departments, they will save a lot of time to solve the problem and eliminate the risk factors in time.

(2) Coal mines should increase investment in mine safety and safety training for mine employees, and strengthen supervision over safety management. Once there is danger, there will be alarm devices or sensors to give early warning. For example, if the gas in the workplace exceeds the limit, there will be methane sensors to give an alarm. The electromechanical equipment should be installed with portable methane detection alarm devices. Managers at all levels cannot ignore any

small safety problem and must take appropriate measures to avoid accidents.

(3) Some regulations should be added or modified. Mine employees should not be punished (reduced salary) due to slow work progress. Some punishment or reward policies must consider the principle of safety first. In addition, the supervision should be strengthened and the illegal coal mines should be strictly investigated.

(4) The feedback or communication channel in the control structure shall be added or improved. For example, when an accident occurs in the mine, the mine practitioners will have corresponding incentive policies to actively report and report, shorten the rescue control channel, make the information feedback more timely, which is also conducive to rescue operations, and minimize the loss of the accident. In addition, many feedback channels should be added. For example, each department should establish a feedback channel to check the contents of the documents ordered by each controller and transmitted from other departments.

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