Research on self-organized safety protection mode for internal fire in coal mine

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ABSTRACT. *In order to better prevent fire accidents in coal mines, this paper proposes a self-organized safety protection model for internal fires in coal mines, and analyzes and studies its constituent elements and their relationships, the formation process and evolution mechanism of the model, and the conclusion: The fire self-organizing safety protection mode includes four components:"monitoring (system platform) and dispatching agency", "departments related to fire management", "downhole operators" and "sensors", which are formed under the combined action of internal and external factors ; The natural evolution of a model is actually a self-organizing evolution, and its self-organizing evolution trend is determined by its own characteristics, and the coordinated and orderly dynamic development of the natural evolution of the model is both the result of the interaction of various elements and the acceleration of the model itself The development of domestic demand, the formation and evolution of the model are also the process of self-organization of the model through the basic functions of its constituent elements, and the improvement of the reliability of the four constituent elements of the model is the driving force for the evolution of the model and the core of the evolution of the model It is the improvement of the reliability of "monitoring (system platform) and dispatching organization". This research provides a new idea for fire prevention in coal mines.*

KEYWORDS: *internal fire, self-organization, safety protection mode*

1. Introduction

In recent years, fully mechanized top coal caving mining technology has been applied in our country 's coal mines commonly and the trend that mining depth is increasing quickly is being presented, which causes that the danger of coal spontaneous combustion in coal mines gradually[1-2]. According to a survey, the area of the spontaneous combustion coal seam and the easily spontaneous

combustion coal seam accounts for more than 90% of the amount of the coal mines in our country; in all mine fire accidents, the mine fire accidents caused by coal spontaneous combustion occupy from 85% to 90%. The internal fire in coal mine influences and restricts the safe and efficient development of the coal mine [3-4]. Therefore, a reliable safety protection mode for internal fire in coal mine must be established, which makes individuals, as the response subject, response selfly and inmediately and gets manual intervention introduced inmediately in the pre-disaster stage of the internal fire in coal mine. The mine fire accident can be avoided.

The self-organized safety protection mode can make safety self-management come true, so many scholars have begun to research. Li Shuang[5] examined the formation mechanism of a safety culture on coal interprises on the basis of cybernetics and self-organization theory and analysed the elements of the coal mine safety culture and the relationship among them. Yin Hong cai and others[6] described and analysed the dynamic evolution process of the generation, formation, development and decline of the coal interprise in nonlinear systems on the basis of self-organized behavior theory. Liu Nian ping[7] analyzed the power rate about accidents of people died in coal mine and people died in coal mine by gas and found that there is a character of self-organized criticality in Chinese coal mine accidents. Cai Wei ling [8] and others proposed how to restruct the self-organised group by analysing and reasoning the present self-organization theory deeply and making the second team of complex driving in HuoZhou Coal and Electricity Company as the research target. Wang man [9] applied the self-organization theory to analyse self-organizaiton characteristics of the coal mine safety management system and considered that there are characters of self-organization and opening in the coal mine safety management system the interaction among the elements is a complex and nonlinear effect. Although the self-organization theory has been applied abundantly in the research on coal mine safety management and protection, the self-organization theory isn't used frequently in the research on the protection of the internal fire in coal mine. Thus, the self-organized safety protection mode for internal fire in coal mine will be put forward in this article and the related research will be carried out, which provides a new thought for the protection of the internal fire in coal mine.

2. Research on self-organized safety protection mode for internal fire in coal mine

The self-organized safety protection mode for internal fire in coal mine proposed in this article is a safety protection mode that in the case where the response is required on the pre-disaster stage of the coal mine internal fire, the elements of the mode are able to response themselves inmediately and efficiently and the development of the disaster can be contained on the abnormal stage.

2.1 Self-organization theory

The involved self-organization theories are synergetic theory and catastrophe

theory in the self-organized safety protection mode for internal fire in coal mine. Synergetic theory researches the mechanism and common law that under the external conditions, the synergistic effect generated by the nonlinear interaction among all subsystems of the system makes the system evolve into the orderly state from the disordered state, evolve into advanced orderly state from the inferior orderly state and evolve into the disordered state from the orderly state[10]. The catastrophe theory applies stability theory for investigating the transition of a process from one stable condition to another stable condition; the transition from a steady state to a new steady state through an unstable state is a mutation process [11].

2.2 The elements of the model and their relationships

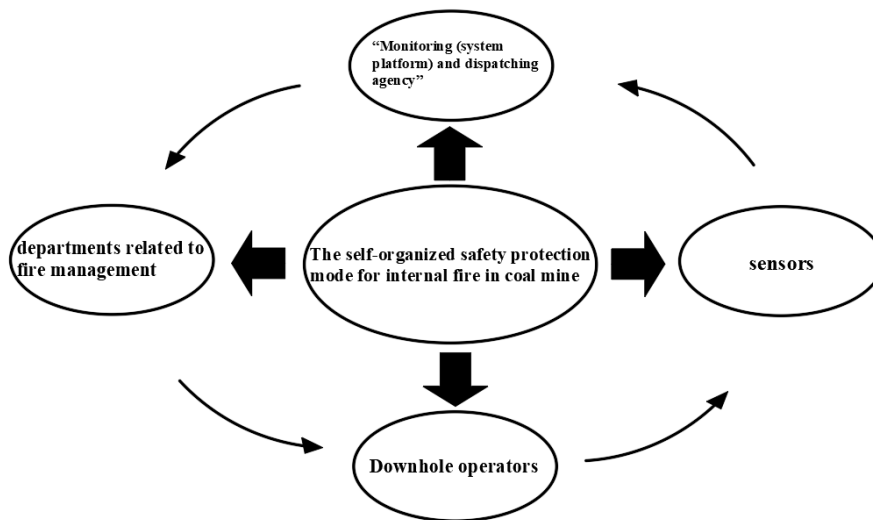*2.2.1 The analysis of elements*

Figure. 1 Division of internal components of the self-organized safety protection model due to fire in coal mines

The safety protection model in coal mine always presents the high complexity on the aspect of structure and in the process of operation. According to the structural characteristics of safety protection model, in this article, the elements of self-organized safety protection mode for internal fire in coal mine are divided into four subsystems"monitoring (system platform) and dispatching agency", "departments related to fire management", "downhole operators" and "sensors", which has been showed in figure 1. The model regards "ensuring production safety in enterprise" as the starting point and it is a system which consists of the human

resource factor, the management mechanism factor, the safety culture factor and so on and has the certain self-organization[12-14]. When the pre-disaster abnormality arises underground, "downhole operators" or "sensors" have to return the temperature of the underground coal seam to "monitoring (system platform) and dispatching agency" and "monitoring (system platform) and dispatching agency" make decision for "departments related to fire management" in accordance with the returned abnormality. Then, "departments related to fire management" will response according to the decision from "monitoring (system platform) and dispatching agency".

2.2.2 The analysis of the relationship among elements

There is a relationship among the four elements of the model. "monitoring (system platform) and dispatching agency" is taken as a core and "departments related to fire management", "downhole operators" and "sensors" interact and improve continuously by themselves around "monitoring (system platform) and dispatching agency", which is showed in figure 2.
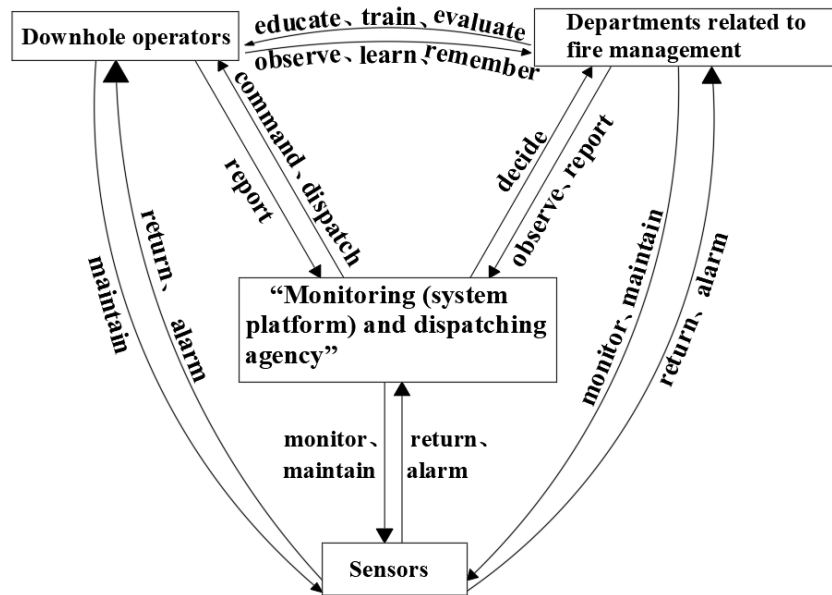

Figure. 2 The relationship between the components of the self-organized safety protection model due to fire in the coal mine

(1)The interactions between"monitoring (system platform) and dispatching agency"and "departments related to fire management","monitoring (system platform) and dispatching agency" and "downhole operators", "monitoring (system platform) and dispatching agency"and "sensors"

①On the stage of the pre-disaster abnormality of internal fire,"monitoring (system platform) and dispatching agency"is responsible for orderring "departments related to fire management"to implement the manual intervention and"departments related to fire management"must implement the manual intervention based on the decision of "monitoring (system platform) and dispatching agency" and report the temperature of the coal seam real-timely.

② When the temperature of the coal seam possessing the spontaneous combustion tendency is abnormal in the mine, "downhole operators" are supposed to make equipments off and retreat. At the same time, they have to report the abnormality to"monitoring (system platform) and dispatching agency"; "monitoring (system platform) and dispatching agency" needs to direct "downhole operators" to make equipments off and retreat and dispatch someone to examine the origin of the abnormal temperature.

③ "Sensors" are the component of the monitoring system. Thus,"monitoring (system platform) and dispatching agency" should pay attention to the maintenance of "sensors" and predict the probality of the abnormality by observing the trend of the returned temperature and whether the corresponding decision must be made should be considered and so on. Meanwhile, it must be guaranteed that "sensors" can give "monitoring (system platform) and dispatching agency"feedback on the temperature immediately and reliably.

(2) The interaction among"departments related to fire management", "downhole operators" and "sensors"

① "departments related to fire management"and "downhole operators"."departments related to fire management" must enhance the daily training of occupational safety education and irregular assessment for "downhole operators". "Downhole operators" have to participate in the training and assessment organized by "departments related to fire management"on time and learn and remember the contents and observe them unconditionally.

②"departments related to fire management"and "sensors". For the prevention of fire, "departments related to fire management"should regard the data recorded by "sensors" as an important basis and pay attention to the maintenance of "sensors" such as debugging and correcting "sensors" and so on. In the meanwhile, it must be guaranteed that "sensors" are able to monitor, record and return the temperature reliably.

③ "Downhole operators" and "sensors". "Downhole operators" should avoid "sensors" being damaged in working and "sensors" are supposed to send the alarm signal to remind "downhole operators" to make the corresponding response in a minute such as stopping the electricity and retreating.

2.3 The analysis of the formation and evolution mechanism of the model

2.3.1 The analysis of the formation of the model

The formation of the self-organized safety protection mode for internal fire in coal mine has been showed in figure 3. The self-conditional factors of the four elements are the internal factors of the formation of the protection model. They are: the reliability of the measurement and control substation, the stability of the central station, the reliability of the ventilation system, the reliability of the grouting system, the responsibility of working, the operators' quality of profession and so on. The coal enterprise's management status is the external factor of the formation of the protection model and consists of the degree of clarification of responsibilities, the degree of perfection of the system, the degree of effective execution, the degree of supervision and management, the degree of management level and so on. The formation of the model is the outcome interacted by the internal factors and the external factors[15-18].
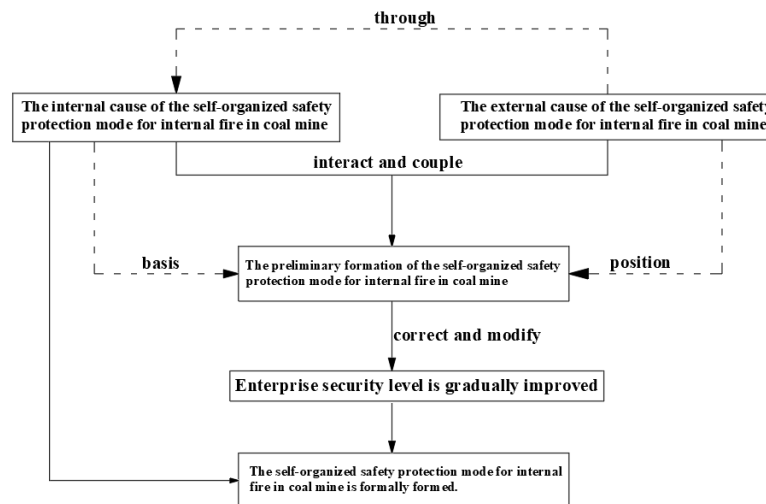

Figure. 3 Formation process of the self-organized safety protection mode for internal fire in coal mine

2.3.2 The analysis of the evolution mechanism of the model

(1) The analysis of the evolution law of the self-organized safety protection mode for internal fire in coal mine

The evolution of the self-organized safety protection mode for internal fire is actually a self-organized evolution and a complicated and dynamic nonlinear process. In the meanwhile, the self-organiszd evolution is also an essential

mechanism that the safety protection model can adapt to the change of external factors and environment. The trend of the model's self-organized evolution depends on the characteristics of the model, not on the individual's subjective will. At the beginning of the operation of the model, workers probably feel confused or have a smattering of knowledge. They don't know how to work correspondingly and concretely. However, along with the circulation and advance of the working, they will gradually explore an effective and reasonable solution associated with the safety protection model. By communicating, a steady working model will be made gradually and workers understand what they should do their woking posts. When the steady working model makes the safety level of the coal enterprise upgrade continuously, the working model will be popular with individuals naturally.

(2) The principle of the evolution of the self-organized safety protection mode for internal fire in coal mine

The safety protection mode for internal fire proposed in this article has the openness and the self-organization and it is a complex and organic whole functioned by the mechanism of the multiple circulation[19-20]. In the opinions of synergetic theory, the coordinating force among the elements can be manifested by the formula which is as follows:

$$F = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$

(1)

From the formula (1), it can be known that when θ is 0, F=F1+F2, which manifests that the resultant force will reach the maxium and its direction is as the same as the two forces' under the condition that the two forces' directions are identical; when θ is π, F=F1-F2, which manifests that the value of the resultant force is the difference between the two forces and its direction depends on the direction of the stronger under the condition that the two forces' directions are opposite and the value of the resultant force will be 0 under the condition that the values of the two forces are identical. From the mechanics law, an important enlightenment that the ordered development of the model will probably be ensured if the attempt and belief of elements of the self-organized safety protection mode for internal fire in coal mine are same will be obtained. The ordered development of the evolution of the model is not only the outcome interacted by all elements but also the domestic demand of the rapid development of the model.

(3)The self-organization model of the executive ability in the evolution of the self-organized safety

Protection mode for internal fire in coal mine

The formation model of the executive ability in the evolution of the self-organized safety protection mode for internal fire in coal mine is showed in the figure 4.

On the basis of synergetic theory, under the condition that the external force for the enterprise is permanent, the description model of the mode can be established. In the model, the construction of the mode is regarded as a deep and important work in

coal interprise safety management. In the meanwhile, the executive ability[21] of the mode is the ability to complete the plan of the establishment of the safety protection mode under the condition that the general guideline of safety management in coal interprise doesn't be violated and it is the role of the promotion of the safety level of coal interprise. The self-organization model of the executive ability of the mode is as follows:

$$dE/dt = -kE + g(p_1, p_2, p_3, p_4) + F \qquad (2)$$

$$dp_i/dt = -k_i p_i + g_i(p_1, p_2, p_3, p_4) \qquad (i = 1,2,3,4) \qquad (3)$$

In these formulas: p_1, p_2, p_3, p_4—"monitoring (system platform) and dispatching agency", "departments related to fire management", "downhole operators" and "sensors"; E—the executive ability of the self-organized safety protection mode for internal fire in coal mine; k—the relationship between the shift rate of E and the original state of E; k_i—the relationship between the shift rate of p_i and the original state of p_i; g—the influence of the synergy of all elements on the evolution of the executive ability of the mode; g_i—the influence of the synergy of all elements on the evolution of p_i; F—the permanent external force; t—time.

In the model, "dE/dt" is the outcome of the formation and evolution of the safety protection mode and it is always influenced by the original state of the enterprise and effected outside. Meanwhile, it is influenced more by the synergy of the basic functions of all elements. The formula (3) has explained the evolutions of the basic functions of all elements in coal interprize separately and presented the internal self-organization mechanism of the mode that every element is not only influenced by its original state but also by the synergy of the functions of all elements. The evolutions of the basic functions of all elements and the formation of the safety protection mode are inseparable from the self-organized process of the enterprise and the evolution of the basic function of any element can also lead to the evolution of the basic functions of other elements [22]. Therefore, the formation and evolution of the safety protection mode is the mode's self-organized process operated by the basic functions of all elements and the outcome of the transition from the mode's original state function to the mode's present state function. The evolution of the self-organized safety protection mode for internal fire in coal mine is irreversible.

(4)The mechanism of the evolution of the self-organized safety protection mode for internal fire in coal mine

The promotion of the reliability of the four elements is a power of the evolution of the mode. "downhole operators" or "sensors" can return the pre-disaster and abnormal signal to "monitoring (system platform) and dispatching agency"in a minute and "monitoring (system platform) and dispatching agency" is able to make decisions for"departments related to fire management"according to the returned abnormality immediately. Then,"departments related to fire management"has an ability to make the mannual intervention efficiently in no time in order to come true the pre-disaster response. Provided that the safety level of the coal interprise has upgraded by using the safety protection mode for a long time, the protection mode

will be adopted by the managers and workers. Simultaneously, the mode can be modified and improved in a way in accordance with the actual situation in the process of operation, which makes the mode as a working mechanism and popular with individuals gradually. Now that "monitoring (system platform) and dispatching agency"is the hub of the self-organized safety protection mode for internal fire in coal mine, the core of the evolution of the mode is the promotion of the reliability of "monitoring (system platform) and dispatching agency".

3. Conclusion

The self-organized safety protection mode for internal fire in coal mine includes four elements"monitoring (system platform) and dispatching agency","departments related to fire management","downhole operators"and"sensors". Simultaneously, there is a relationship among the four elements of the model. "monitoring (system platform) and dispatching agency" is taken as a core and "departments related to fire management","downhole operators" and "sensors" interact and improve continuously by themselves around "monitoring (system platform) and dispatching agency".

The formation of the self-organized safety protection mode for internal fire in coal mine is the outcome interacted by the internal factors and the external factors. The self-conditional factors of the four elements are the internal factors of the formation of the protection model and the coal enterprise's management status is the external factor of the formation of the protection model.

The evolution of the self-organized safety protection mode for internal fire is actually a self-organised evolution and the trend of the model's self-organised evolution depends on the characteristics of the model. The ordered development of the evolution of the model is not only the outcome interacted by all elements but also the domestic demand of the rapid development of the model. The formation and evolution of the safety protection mode is the mode's self-organised process operated by the basic functions of all elements and the outcome of the transition from the mode's original state function to the mode's present state function. The promotion of the reliability of the four elements is a power of the evolution of the mode and the core of the evolution of the mode is the promotion of the reliability of"monitoring (system platform) and dispatching agency".

Acknowledgements

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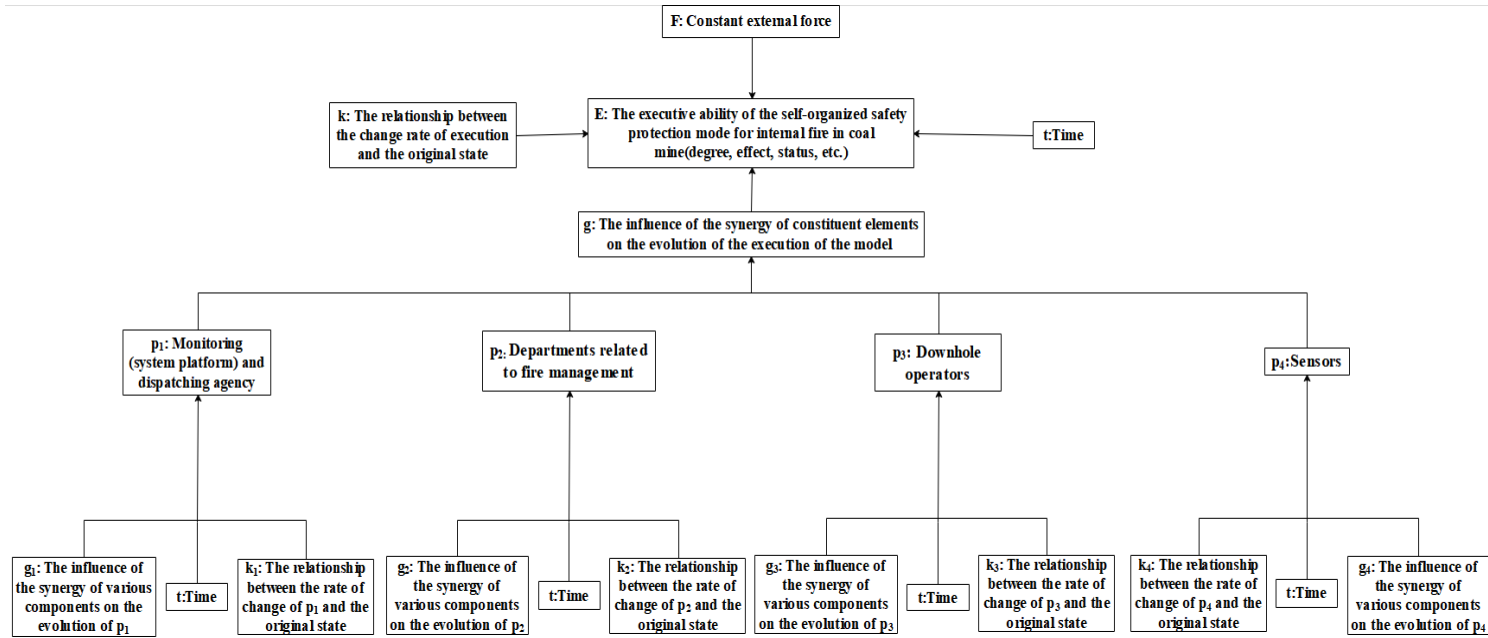
Figure. 4 Formation model diagram of the executive ability of the self-organized safety protection mode for internal fire in coal mine