Review on Risk Early Warning of Coal-Based Synthetic Oil

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Abstract. In recent years, with the maturity of coal chemical technology, coal chemical industry has been developed by leaps and bounds. The following is the increase of coal chemical enterprises. The increase of coal chemical industry enterprises are naturally accompanied by the rising trend of coal chemical accidents. Because accidents of coal chemical industry are easy to cause heavy casualties, property losses and environmental pollution, it is important particularly to prevent accidents of coal chemical industry. In order to understand the research status of coal-based synthetic oil risk early warning, this article mainly reviewed the research status and the main research achievements of the risk index system of chemical industry in recent years. Taking risk identification, risk evaluation and risk early warning process as the main line, and compared the advantages and disadvantages of different early warning indicators system. And based on the study of coal-based synthetic oil related process flow, we forecasted the development trend of the risk early warning for coal-based synthetic oil.

1. Introduction
Coal-based synthetic oil project has the industrial characteristics of flammable and explosive, toxic and hazardous products gathered in the park, serious consequences and regional industrial characteristics of a large cluster, large-scale, large circulation. This determines that this area has high security risk and potential safety problems. So the coal-based synthetic oil safety production accident risk warning is extremely important. At present, at home and abroad, the risk early warning methods of coal chemical industry mainly include analytic hierarchy process, accident causing theory, hazard identification, Hazard and Operability Study method, Preliminary Hazard Analysis method and Event Tree Analysis method, etc. These methods have played an important role in the early warning of coal chemical enterprises, but there are still some shortcomings, such as analytic hierarchy process has too large data and the weight of the index is difficult to determine; Hazard and Operability Study method is only applicable to the initial and design phase of the program, etc. Therefore, how to study the coal-based synthetic oil production technology and choose the risk early warning program is a difficult problem.

2. Coal-Based Synthetic Oil and its Characteristics
Coal to oil is to convert coal into a liquid that is similar to oil. Its product is a substitute for oil. Coal-based synthetic oil, which is known as coal based liquid fuel synthesis technology, has two ways: direct liquefaction and indirect liquefaction. Coal is a solid fuel with high carbon content but low hydrogen content (only 5%) (Hydrogen / carbon ratio). The coal can be converted directly or indirectly
and improve the hydrogen / carbon ratio by de carbonization and hydrogenation. The direct or indirect conversion process is coal-based synthetic oil [1].

2.1. Mode of Production
Direct liquefaction also is known as “hydrogenation”. The process is by the way of direct catalytic cracking of coal in the high temperature, high pressure and the catalyst, so that its degradation and hydrogenation transform into liquid oil. For example, China Shenhua direct coal liquefaction demonstration plant has three produce lines, including coal liquefaction, hydrogen stable, hydrocracking, coal to hydrogen and hydrogen gas, reforming extraction, solvent deashing, sulfur recovery, urea, coal preparation, catalyst preparation, light hydrocarbon recovery, desulfurization, containing sulfur wastewater provided, air classification [1].

The indirect liquefaction of coal is to produce the raw material gas first, next the synthetic reaction is carried out after the purification, and then the process of the oil is produced. Its production process can be divided into three major steps, first: synthesis gas; then: catalytic reaction; last: upgrading. Currently, indirect liquefaction have been realized industrial production in some countries which mainly divided into two processes, one is the Fischer Tropsch process, raw material gas direct synthetic oil; the other is the Mobile technology, by the feedstock gas for methanol synthesis and methanol into gasoline [2].

2.2. Characteristics
There are unsafe factors in the production of coal-based synthetic oil, whether the indirect liquefaction or direct liquefaction, the unsafe factors exist in the following four aspects:

1. Flammable, explosive, toxic and strong corrosive. In the process of recovery and purification of coal chemical products, there are many kinds of chemical reagent (including products, raw materials and intermediate products) produced and used, such as oil, benzene, naphthalene, asphalt etc. These products are flammable, explosive, toxic and corrosive.

2. High temperature, high pressure and high flow rate. High temperature, high pressure and high flow rate are needed in many production processes of coal chemical industry, which are easy to cause fire and explosion accident.

3. The process is complex and the operation is strict. There are many kinds of products in coal chemical industry these usually need high temperature, high pressure and high flow rate. Therefore, the operation must be meticulous. A slight mistake could lead to an unexpected accident.

4. There is large impact on the environment. As mentioned above, there are many unsafe factors in chemical production. Safety technology and management work in the chemical production status are more important. It is necessary to carry out risk early warning research.

3. Risk Early Warning Research
Zhou [3] defined the risk early warning of the enterprise safety production accident as the comprehensive analysis and evaluation of the factors affecting the enterprise security, and makes the forecast and warning for the possible accident risks. The purpose is to develop contingency plans to mitigate risks in order to minimize the risks to which the business may suffer. From the early warning activities in the order of time, Yao [4] summarized early warning into 3 stages: risk identification, risk evaluation and risk early warning.

3.1. Risk Identification
Risk identification is the first step in the early warning of risk, which is to combine the specific circumstances of the early warning object, and screening and revising the corresponding risk information, in order to determine the various risks in the system. Yang [5] believed that the search for the source of risk identification is not only the basis of the analysis of the warning signs, but also to exclude the premise of the police. In the enterprise safety production accident risk early warning, the police source is the root cause of the accident. Therefore, the identification of early warning factors
can be determined by the accident causing theory and major hazard identification. Chinese scholars began to study the theory at the end of the 20th century. Qian [6] put forward the model of accident causing catastrophe. By using the catastrophe theory of differential equation, the theory divided the factors into two control parameters. And production capacity or system function is called state parameter. So a catastrophe model is established for the cause of accident. Ma [7] proposed safety rheology-catastrophe theory, and thought that the accident was from rheology to mutation, and established quantitative mathematical model. It also provided a new way for the coal mine accident qualitative analysis, quantitative research and realization of accident mechanism. Chen [8] presented two kinds of hazard theory: system occurred or accidental released of hazardous energy and substances called the first class of hazard; and lead that limit the energy measures failure or damage of unsafe factors called the second class of hazard, and the accident is result of the interaction of two types of hazards. Tian [9] put forward the three class of hazard, including program organization, organization culture, rules and regulations, system, and thought that the three class of hazard is the root cause of the accident.

3.2. Risk Evaluation
Risk evaluation is the core of the early warning process, and the warning is made on the basis of risk evaluation. We can use a comprehensive integration method to evaluate to determine the risk factors and the degree of risk. The system can operate normally if in the acceptable range. If beyond the scope, then enter the risk early warning stage. Research on risk assessment started in 1980s. Zhao [10] divided it into 4 categories: qualitative evaluation method, index evaluation method, probability risk evaluation method and semi quantitative evaluation method. In 1991, the research was listed as the national “eight five” key issues of science and technology research. Then the former Ministry of Labor Institute of labor protection and other units completed the “flammable, explosive, toxic and major hazard identification, evaluation technology research” and the evaluation of major hazard sources was divided into two aspects: the inherent risk and the actual risk evaluation, which was a sign of our country's security evaluation from qualitative evaluation to quantitative evaluation. After the combination of risk evaluation research and computer technology and mathematics method, the fuzzy probability evaluation method and the risk assessment system based on the artificial neural network technology and the computer network technology appeared [11].

3.3. Risk Early Warning
The risk evaluation can get the risk value. And then compared the risk value with the early warning threshold, we can get early warning results. Through the signal, sound and other means to report the warning level, we can carry out risk prevention and control. According to the early warning mechanism, Gu [12] summarized early warning methods into 5 kinds: black early warning, yellow early warning, red early warning, green early warning and white early warning (table 1).

4. Application of Risk Early Warning in Chemical Industry
Analyzed the safety status of the 39 coal chemical industry park and combined with the characteristics of the coal chemical industry park, Xu [13] put forward two aspects of the causes and safety precautions to consider coal chemical industry park safety warning indicators. Due to the accident occurred involving the environment, equipment, management system, people and other factors; we need to identify these dangerous sources accurately and rapidly. Therefore, according to the impact of the various early warning indicators, we use the improved analytic hierarchy process to analyze the weight of the index, and combine with the BP neural network to construct the security warning model of coal chemical industry park. The early warning model based on this method is relatively good, but the feasibility and practicability are still to be studied.

Through identifying, monitoring, warning, expert analysis system, emergency plan database, triggering security early warning system, Zhang [14] achieved that it can quickly, ordered the implementation of effective measures to curb the occurrence of safety accidents in production after the
abnormal situation occurred. Establishing hazard real-time monitoring and automatic emergency early warning information platform, and combined static safety and dynamic management, before the accident when a fault occurs on the instantaneous change of data real-time system to determine the correct, timely and automatically release emergency instructions, make relevant personnel quickly to make effective measures, effectively curb the occurrence of safety accidents in production. This method is mainly to start with the risk sources of production equipment, and ignore the human factors and management defects.

Liang [15] divided the risk sources into human factors, material factors, environmental factors and management factors. We identified hazard source from macro to micro, from small to large comprehensive, systematic, orderly, in order to avoid missing items. This method should be gradually carried out from the project site, layout, road, building materials, production processes, production equipment, equipment, operating environment, management measures and so on. The method is theoretically studied, and the method is not clear.

Table 1. Characteristics and practical range of different early warning methods.

| Early warning methods | Characteristics                                                                 | Practical range                                                                 |
|-----------------------|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Black early warning   | Based series of the alarm, the direct early warning                            | Used in the economic field, such as the expected synthetic index method, the economic diffusion index method, the commercial index method, the economic fluctuation diagram method, etc. |
| Yellow early warning  | Use warning signs for early warning                                            | Applicable to various fields, the most commonly used                             |
| Red early warning     | According to the warning signs and other environmental and social factors     | Mainly used for qualitative analysis                                             |
| Green early warning   | According to the growth situation of the police, using the remote sensing technology to monitor the change of the status of the system | Applied to forecast the development of economy and agriculture                   |
| White early warning   | Using measurement techniques to predict                                        | Exploration stage                                                                |

Han [16] analyzed the application of artificial mode HAZOP safety evaluation technology and the advantages and disadvantages of manual mode HAZOP security evaluation technology. He also carried on the thorough analysis to the symbol under the condition of the symbol to the computer aided pattern HAZOP security appraisal technology to select the evaluation technology suitable for the chemical enterprise. By constantly improving its practical value and efficiency, we can promote the healthy development of chemical enterprises. But it didn’t establish a warning system to prevent the occurrence of accidents.

Zhang [17] explained that the chemical industry often produced some flammable, easy poisoning, explosive chemicals. Chemical industry is a lot of unsafe factors, and it is dangerous. In the production process, chemical enterprises usually use raw materials which are dangerous. The production process is complex and requires strictly. Many chemical products need to be in high temperature, high pressure, low vacuum and other harsh environment. And using HAZOP, PHA, ETA to identify risk, monitor risk and avoid risk. It is still only a theoretical research on the early warning of chemical enterprises.

5. Conclusion
At present, risk early warning research is still in the initial stage. There are some problems in the early warning research:
Focusing on the research of the index processing method and ignoring the in-depth study of the principle, ignoring the analysis of the source of the police, while the early warning model test and early warning system evaluation research are not deep enough.

At this stage, the risk warning mainly is used in in the military field, economic field and agriculture and forestry fields. Most of the research on risk early warning is still a theoretical model, especially in the field of coal chemical industry.

The production process is complex and the operation requirements of production equipment are high. It will be a major development direction for coal chemical industry enterprises to establish a suitable risk early warning system, which is a major source of risk.

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Reference
[1] Chen L and Liu J 2006 *Guizhou Geology* 2006 23 168-174.
[2] Wei X, Zong Z and Qin Z 1998 *Coal Conversion* 21 21-23.
[3] Zhou R 2008 *Business China* 6 247.
[4] Yao J 2010 *China University of Geosciences* (Beijing) 12 336-345.
[5] Yang T and Dang G 2014 *Journal of Safety and Environment* 4 123-129.
[6] Qian X and Chen B 1995 *China Safety Science Journal* 2 1-4.
[7] Ma S and He X 1995 *China Safety Science Journal* 5 9-12.
[8] Qian X and Chen B 1994 *China Safety Science Journal* 3 16-21.
[9] Tian S and Li H 2007 *China Safety Science Journal* 1 10-15+177+179.
[10] Zhao J and Zhang Y 2005 *Pressure Vessel* 12 50-52.
[11] Feng N, Li M and Kou J 2006 *Computer Engineering and Applications* 6 24-26.
[12] Gu H, Liu W and Zhou Z 2007 *Journal of National School of Administration* 1 49-52.
[13] Xu X 2014 *China Coal* 11 13-17.
[14] Zhang W, Qin Q and Wang C 2008 *Shandong Coal Science and Technology* 3 83-85.
[15] Liang J 2015 *Chemical Engineering Management* 5 248-250.
[16] Han B 2015 *Guide of Sci-tech Magazine* 12 213.
[17] Zhang H 2015 *Chemical Engineering Management* 19 129.