RESEARCH ON EARTHQUAKE DISASTER CHAIN MODELS AND HAZARD ASSESSMENT

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ABSTRACT:

The disaster chain theory is proposed to study the development process of complex earthquake disaster. Taken the earthquake disaster of petroleum and gas system as an example, the forming process and the mechanism of the earthquake disaster chain are researched. And three kinds of physical models are established to describe the forming process of the earthquake disaster chain. The schematic drawing of the earthquake disaster chain of petroleum and gas system is given and the possibility of disaster is studied by applying the hazard analysis method. Therefore, this paper provides the new ideas and the methods for earthquake prevention and disaster reduction.

KEYWORDS: earthquake disaster chain; physical model; secondary disaster; hazard assessment

1. INTRODUCTION

The earthquake disasters are potential tremendous threat to human society. The strong earthquake will cause direct damage to buildings and structures, and may also trigger a series of secondary disasters, such as fire, explosion, debris flows, floods, gas leakage and diffusion, etc. The structural damage and the secondary disasters arising out of the earthquake are collectively known as the earthquake disaster (Z. D. Zhao et al. 2005). Previous studies on the earthquake disaster mostly focus on the individual disaster. Therefore, it lacks systemic, macro and comprehensive study ways and means for the whole disaster process. With the development of urbanization and industrialization process, the earthquake disaster gradually shows some complex characteristics, such as diversity, randomness, sudden and so on(T.Q. Li and Z. D. Zhao 2006), which makes the single ways and means unable to deal with the complicated earthquake disaster. Accordingly, the comprehensive and systematic methods and theories are required to be the basis to study such complex disaster process. In this paper, the idea of disaster chain is proposed and used to study the complex process of the earthquake disaster, in which a typical earthquake disaster of the petroleum and gas system is taken as an example.

2. EARTHQUAKE DISASTER CHAIN

In the development process of the earthquake disaster, there may be many disaster forms; each has its own generation and development process. In this process, various disaster forms do not exist in isolation, and they form the whole seismic disasters contact and intertwine with each other by certain ways. Here, we used the idea of disaster chain to research the whole disaster process. If the various forms of disaster are deemed “rings” in the chain, the interaction of disasters are deemed the “nodes” that link the “rings”, therefore the complicated process of the earthquake disaster can be simplified as the forming and developing process of the disaster chain. Along with the growth and continuation of the disaster chain, the types and the extent of the disaster increase continuously, which leads to serious results. From the view of the disaster prevention engineering, it is as far as possible to eliminate the “nodes” and cut off the links between disasters to control the disaster chain, which will makes the loss of disasters minimum.

The formation of the disaster chain requires certain conditions. Firstly, more than two disasters are needed during the course of a disaster because one disaster, can not result in the disaster chain. Secondly, there should

be a certain correlation between the disasters, otherwise which would not form the disaster chain. Moreover, the disaster chain is not a sudden form, but it follows the developing process of disasters, which has the continuity in the time. In view of the disaster chain, there is a “ring”, and a “node” appears after the “ring”, then there is another “ring”, so tightly link to continue.
In the disaster chain, the role of the “nodes” is very important. In disaster chain, "node" embodies the interaction of two disasters. It is the result of former disaster and also is the trigger of the posterior disaster. “Node” likes a bridge between two disasters, the former disaster induces the posterior disaster through the “node”, and then posterior disaster strengthens the former disaster through the “node” in turn. The interaction of two disasters makes the scale of the disasters expand constantly and the results more serious. Therefore, in a sense, if we control the “nodes” that will control the production and development of disaster chain, which can achieve the purpose of earthquake prevention and disaster reduction.

3. DISASTER CHAIN MODELS

For the earthquake disaster chain, there are two main factors, one is the disaster; the other is the “node”. For example, petroleum and gas system have more diverse disaster forms, such as structure damage, fires, explosion and gas leak and so on. These disasters interact through the “nodes”. In this paper, two disasters and their “node” is called as a disaster area. The entire disaster chain is formed by different disaster areas according to a certain order and relations. Structure damage is not only the first disaster in disaster chain, but also is the necessary condition that forms the whole disaster chain. The disaster chain has different developing process, which generally as follows: (1) structure damage →fire →explosion →gas leak; (2) structure damage → explosion → fire → gas leak; (3) structure damage → gas leak →fire (explosion) → explosion (fire). Specific forming process will be different by the influence of environment and conditions at that time.

In each disaster area, the connection way of the “node” is different. According to the different connection way, three physical models have been established to describe the formaing process of the earthquake disaster chain.

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3.1 Series model

Earthquake and fire is a common disaster area in the disaster chain. Normally , there are three “nodes” in this disaster area: the first is the secondary source of the fire(T.Q. Li and Z. D. Zhao 2005), which is mainly the flammable petrochemical raw materials or products; if the fuel had been good sealed and preserved without leakage, it will not cause fire, therefore, the second is the leakage of the source of the disasters; the third is the ignition factor(Various Authors 1992), if there are no ignition factors, even if the flammable materials leak, it will not cause fire. The ignition factors can be the spark that is caused by electrical short circuit; it can also be the spark that is caused by metal collision, or other natural or man-made ignition factors. Some petrochemical products have spontaneous combustion characteristics at normal temperature and pressure, thus special attention needs to be paid for these products. Based on the above analysis, it can be seen that the earthquake and fire are connected by three “nodes”. Fire cannot be triggered in the event of the loss of any one of them, which links much like the way of the series circuit, thus it is defined as the series model. Figure 1 shows the schematic diagram of the series model.

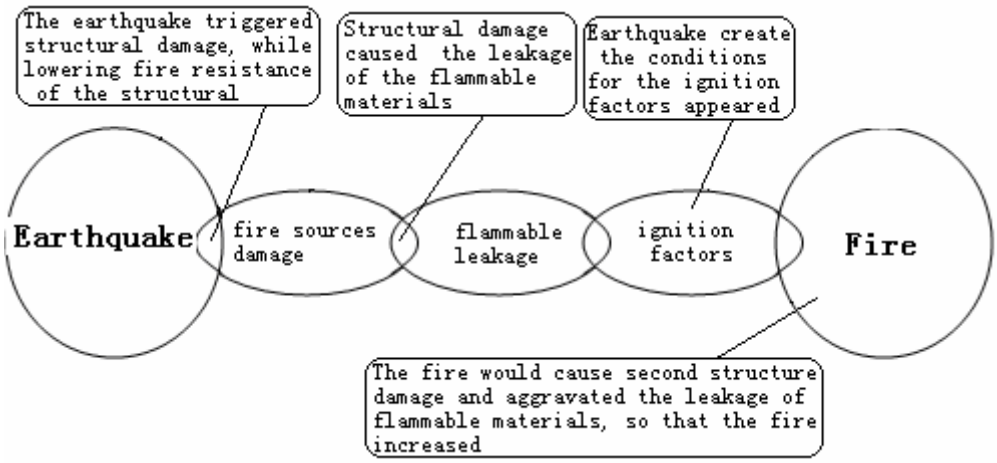

Figure 1 Schematic diagram of the series model

3.2 Parallel model

The disaster chain will continue to transfer after the fire, then the disaster area of fire and explosion is formed. In this disaster area, there are two ways that fire caused explosion. One is that the explosion is triggered by the fire directly when explosive material leak (Corr R.B. et al. 1999); the other is that the fire would increase the temperature of the pressure vessel in the petroleum and gas system, which will make the internal pressure of these vessels increase subsequently, when the internal pressure exceeds the limit, the explosion will occur. The characteristic of this disaster area is that there are a number of ways between the disasters. As long as one exits, the disasters will continue develop. Such kind of connections like the parallel circuits is defined as parallel model. Figure 2 shows the schematic diagram of the parallel model. The explosion is a devastating disaster, the shock wave and the heat have enormous destructive power to the buildings and the equipments in a certain range, which will make the combustible materials further leak and thus lead to fire. The disaster chain expands rapidly following the explosion, of multiple disasters interaction through the "node", so that the consequence of the disasters is more serious.

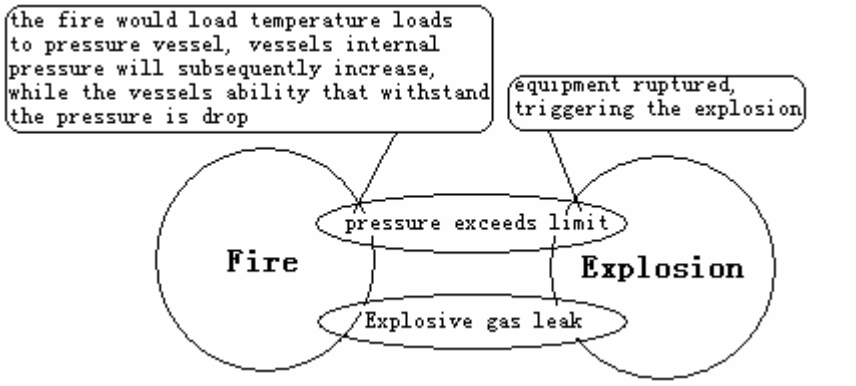

Figure 2 Schematic diagram of the parallel model

3.3 Hybrid model

When the connection way of disaster area has both the series model and the parallel model, it is defined as the hybrid model. Such as earthquake and explosion area, the earthquake will damage the storage equipments for the explosive gas and make the explosive gas leak. When the density of the explosive gas in the air reaches a certain degree, the fire will trigger the explosion. Another way is that the earthquake damages the production equipments, and then the pressure of the equipments will be out of control. Thereby the explosion is triggered directly. The schematic diagram of the hybrid model is shown in Figure 3.

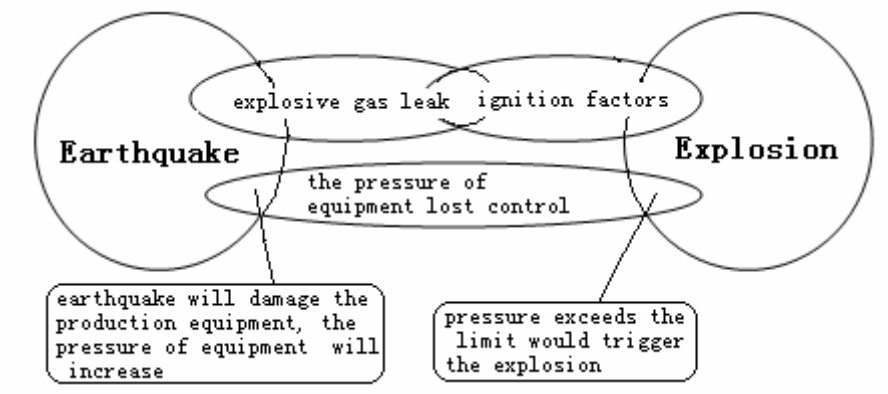

Figure3 Schematic diagram of the hybrid model

The three basic models mentioned above represent the common ways of the connection of the "nodes" in the earthquake disaster chain of the petroleum and gas system. The integrated process of the disaster chain can be obtained by combining them according to different order

4. HAZARD ASSESSMENT OF THE EARTHQUAKE DISASTER CHAIN

The development and continuance of disaster chain requires certain conditions, a new disaster can be triggered by one or several disaster areas happen simultaneously. And many areas of the disaster chain are not sure event, their own have randomness and chanciness. If they are studied as viewed from the probability, and the occurrence probability of the nodes and the areas are determined, the occurrence probability of, the various disasters can be calculated, thus the hazard assessment of the disasters is carried out(Z. D. Zhao et al. 1996).

4.1 Analysis of the earthquake-induced fire

Arranging three basic models according to different order, the integrated disaster chain model of petroleum and gas system can be established, as shown in figure 4. The occurrence probabilities of some disaster areas are assumed through the qualitative methods, ,then the occurrence probabilities of other disaster areas and the secondary fire can be obtained by calculation. In figure 4, the assumed probabilities are marked by boldfaced font, the calculation probabilities are marked in ordinary font. In order to facilitate the study, each part is marked by a number. Assuming that there is a destructive earthquake, then P1 = 1. The probability of structural damage is assumed to be 20%, then P2 = 0.2. And the failure probability of the long distance gas pipelines is assumed to be 70% because they have more joints and easy to be damaged by the earthquake. Similarly it can be assumed that the failure probability of the oil storage tanks is 50%, the failure probability of the production equipments and valves is 30%. In this way, it can be obtained that P3 = 0.2 × 0.7 = 0.14, P4 = 0.2 × 0.5 = 0.1, P5 = 0.2 × 0.3 = 0.06. If the pipelines and the storage tanks rupture, the leakage possibility of the petrochemical raw materials and products is very high，therefore, it can be assumed the leakage probability is 80%. If the equipments and the valves are damaged, the leakage possibility is small, which is assumed to be 60%, thus P6 = 1-(1-0.8P3) (1-0.8P4) (1-0.6P5) = 0.21

Most raw materials and products in the petroleum and gas system are inflammable, thereby the inflammable probability of the leakage is assumed to be 70%, then P8 =0.7P6= 0.147.

Assuming the probabilities of P9, P10, P11 are 10%, 10%, 5%, then the probability of fire induced by the leakage of the raw materials is: PF1=1-(1-0.1P8) (1-0.1P8)(1-0.05P8) = 0.036

The damage of the equipments and the valves will cause the collapsed equipments impact other equipments, the probability of which is assumed to be 10%, then P12=P5×0.1=0.006. And the probability of fire induced by it is assumed to be 60%, then the probability of fire induced by the collapse of the equipments is: PF2 =P12×0.6 = 0.0036.

The damage of the equipments and the valves will cause excessive pressure on the containers, which can easily cause the explosion and then trigger the fire. Assuming the probabilities of excessive

pressure, explosion, fire are 20%, 70%, 80%, then the probability of fire induced by excessive pressure is: P_{F3} =P_{13}×0.8 = 0.0067.

According to the above mentioned, when the destructive earthquake takes place, the probability of secondary fire of the petroleum and gas system can be obtained as follows:,P_F=1-(1-P_{F1})(1-P_{F2})(1-P_{F3})=1-(1-0.036)(1-0.0036)(1-0.0067)=0.046.

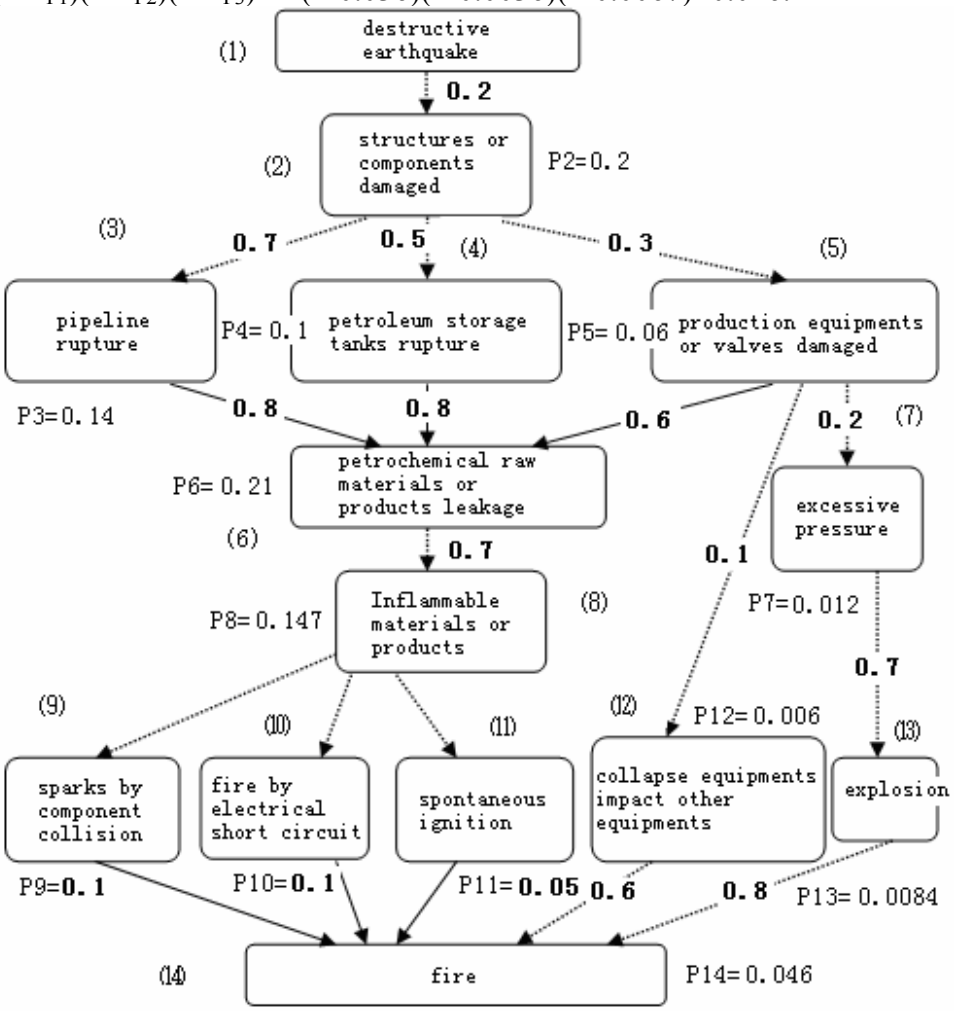

Figure4 the probability analysis of the earthquake-induced fire

4.2 Analysis of the earthquake-induced explosion

Similarly, the probability of secondary explosion can be obtained by using the same principle. The calculation process is shown in Figure 5. There are two trigger ways of explosion, one is the explosion induced by fire,and the other is the explosion induced by the increase of the pressure caused by the equipment damage. Here, the operation is carried out according to the hazard assessment results of the secondary fire. The probability of fire is 0.046; the probability of explosion triggered by the increase of pressure is 0.0084. The high temperature of the fire will increase the internal pressure of the pressure vessels, thus the probability of which is assumed to be 30%, then P_{15}=0.3P_{14}=0.0138. Assuming the probability of the leakage of the explosive products is 60%, then P_{16}=0.6P_{14}=0.0276. The probability of the explosion caused by pressure increase of vessels is assumed to be 50%, then the probability of the explosion induced by earthquake is P_b=1-(1- 0.5 P_{15})(1- P_{16}) (1- P_{13})=0.042.

4.3 Analysis of the earthquake-induced gas pollution

The gas leakage will directly cause the pollution, and combustion and explosion of the petrochemical raw materials or products may also generate a lot of harmful smoke to pollution and destruct the environment, as shown in figure 6. Assuming the probability that the leakage materials are toxic is 70%, then $P_{18}=0.7P_6=0.147$. Assuming the probabilities of the pollution caused by fire and explosion are 20% and 10%. Then the probability of the generation of toxic gas and dust can be obtained as follows

$$P_g=1-(1-P_{18})(1-0.2P_{14})(1-0.1P_{17})=0.158$$

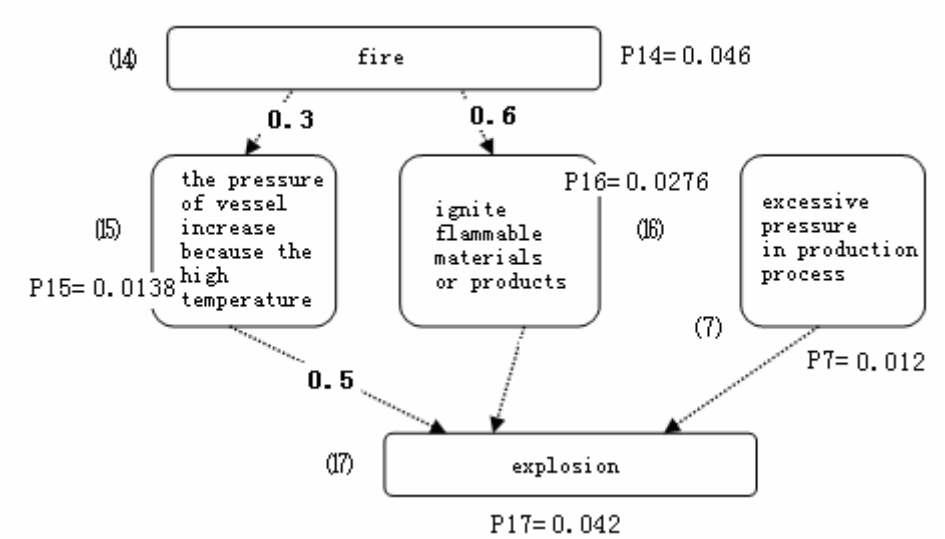

Figure5 the probability analysis of the earthquake-induced explosion

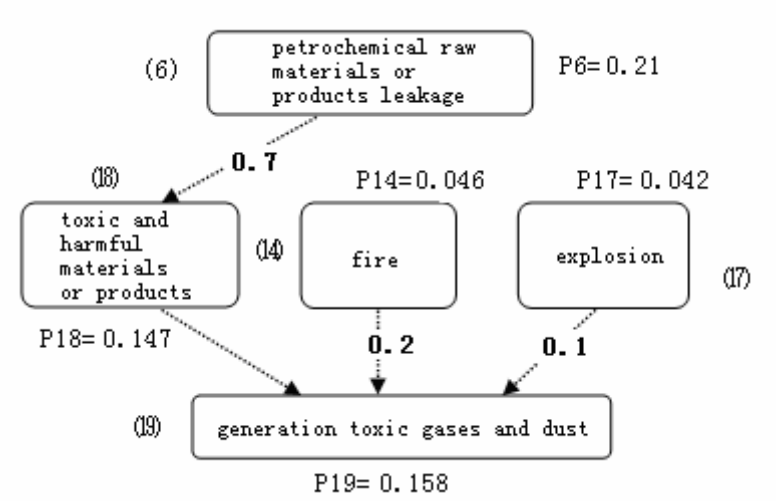

Figure6 the probability analysis of the earthquake-induced gas pollution

It is important to point out that the calculation of this article merely to illustrate the methods and the ideas of the hazard analysis of the disaster chain., In specific applications, investigation needs to be carried out for different systems to obtain more reasonable and precise results..

5. CONCLUSION

In this paper, the theory of the earthquake disaster chain is utilized to study the developing process of the earthquake disaster, the main research results as follows:

(1) Aiming at the complexity and the diversity of the earthquake disaster, the methods of the disaster chain

is proposed to systematically study the developing process of the earthquake disasters, which simplifies the problems and makes easy to take effective measures to prevent and reduce the risk of the earthquake disasters;

(2) The forming process of the earthquake disaster chain of the petroleum and gas system can be generally divided into four areas, including the earthquake fire disaster area, the fire and explosion disaster area, the earthquake and explosion disaster area and the gas pollution disaster area. In this paper, three models are established to describe the different disaster areas of the earthquake disaster chain;

(3) The integrated illustration of model of the earthquake disaster chain for the petroleum and gas system is given. The developing process of the disaster chain is studied by applying the method of hazard assessment, which can assess the occurrence probability of various disasters in quantitative.

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