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Analysis of Domino Effect Based on Bayesian Probability Explosion and Oil Tank Fire in Mixing Tank Area

Analysis of Domino Effect Based on Bayesian Probability Explosion and Oil Tank Fire in Mixing Tank Area

Xi WenHu[1], Cun FengZhang[1,2,*], Xu HaiPan[1]

[1] College of safety Science and Engineering, Nanjing Tech University, Nanjing, Jiangsu, 210000, China

[2]School of resource Engineering, Longyan University, Longyan, Fujian,3640190, China

[*]Corresponding author's e-mail: 12719341@qq.com

Abstract. Based on the domino effect and Bayesian network, this paper establishes the accident probability model of hybrid storage tank area. Taking a chemical storage tank area as an example to analyze the accident domino effect caused by accident parameters such as thermal radiation and explosion shock wave, we analyzed and calculated the damage probability of shock wave over-pressure and pool fire to adjacent equipment in liquefied gas storage tanks by considered that the occurrence of a pool fire accident in a single tank is a result of the incident. The results show that the control measures are combined with the energy transfer sequence of the accident, so that the safety protection measures proposed under this scenario can more effectively ensure the safety of the chemical tank farm.

1. Introduction

With the continuous expansion of the petrochemical industry and the trend of group development, China has vigorously developed chemical parks near the seas and rivers and in resource-rich regions. Due to the existence of a number of major hazards such as flammable, explosive, and toxic in the chemical park, if an accident occurs, it is likely to induce a domino effect and cause a major accident and the domino effect of an accident is often greater than that of a single accident[1]. Therefore, many scholars have conducted extensive research on this issue from different perspectives. Among them, the domino effect is one of the research hotspots. At present, the research on the domino effect mainly focuses on its probability of occurrence and consequences of accidents, and the research in these two areas also constitutes a risk study on the domino effect[2].

Some scholars have combined Bayesian networks[3], directed weighted networks[4], graph theory [5]and other methods into the analysis of domino effects. The study of the effect of domino effect accidents shows that the extent of its coverage and the severity of the consequences are wireless amplification or the order of magnitude jumps which are affected by the probability[6]. However, the study of its probabilities is still not precise and in-depth. It is necessary to introduce the logical relationship, theories and models that can correctly reflect the factors in the accident transfer in the study of the probability of occurrence of the minnow effect.

In this paper, the Bayesian network is used to analyze the simultaneous domino effect scenarios of steam cloud explosion and pool fire, and corresponding control measures are proposed.

2. Calculated theoretical model

2.1. Analysis of accident domino effect in storage tank area

The accident domino scene refers to the analysis of the specific occurrence of accidents and the expansion of the accident. Through the prediction of the accident domino scenario, it can be targeted to the analysis of the accident consequences and the domino effect[7].

Considering the hazard characteristics, storage conditions, and external environmental factors of the chemicals in the mixed tank area, it can be seen that the tank fire, VCE, etc. may be triggered in the tank area after an initial event occurs in a tank in any tank area. BLEVE and other major injuries may happen. Under normal circumstances, explosion accidents are more dangerous [8]. When an explosion is used as an initial accident, rescue and safe evacuation times are less than when the initial event was a pool fire. Therefore, this paper will choose to model and analyze the initial events of the explosion as a domino effect of the accident.

The types and materials of the tanks contained in the tank areas of many chemical parks are all different. If the analysis is conducted as a whole, it will increase the difficulty and workload of the analysis. Therefore, when a fire occurs in a tank area where both the high-pressure tank and the atmospheric pressure tank, it should be subjected to a step-by-step simulation and then be calculated.

2.2. Bayesian Network Modeling of Minot Effect in Mixed Tank Zones

- Analyze the domino effect of steam cloud explosion in high pressure storage tanks
- Calculate the damage probability of atmospheric cloud tank explosion
- Determine the initial accident of the atmospheric tank area caused by the explosion of the steam cloud and analyze the domino propagation path
- Determine the final accident of the domino effect
- Draw the Bayesian network
- Calculate the prior probability based on the equipment damage probability model and complete the conditional probability table
- Calculate the posterior probability of all domino effect accident scenarios to obtain the maximum posterior probability
- Determine the best control point for the accident, combine the accident chain, and give the control measures

2.3. The domino effect probabilistic analysis of steam cloud explosion in high-pressure storage tanks during initial events

The probability of damage to people and equipment at different distances from the explosion over-pressure of the explosion tank can be calculated When a vapor cloud explosion occurs in a LPG storage tank, according to Valerio Cozzani et al.'s Probability Model of Explosion Shock Wave Domino Effect and Human Damage Probability Calculation Formula [9]. Transform to a specific probability and fit into a graph by Equation (1). The curve diagram is used to estimate the damage probability of explosive tanks to equipment around different distances.

$$P = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{Y-5} e^{-u^2/2} du \qquad (1)$$

2.4. Bayesian Network Reasoning of Derived Events for Pool Fires in Atmospheric Pressure Tanks

The traditional Bayesian network is a directed acyclic graph that starts at the parent node and points to the child node through a unidirectional arrow. The establishment of Bayesian network in the domino effect of pool fire can not only describe the degree of influence between various elements according to the conditions of the Bayesian network, but also serve as the basis for the reasoning of the accident propagation path. At the same time, Bayesian network statistics can be used to compensate for the domino effect's accident path uncertainty[10].

Applying Bayesian network inference to pool fire domino effect can quantify the interrelationships among various elements in the domino effect and obtain the most contribution to the domino effect according to the Bayesian posterior probability, thus effectively cutting off the propagation path. In this model, the damage probability of the target device caused by the heat radiation of the pool fire is obtained by the probability function of Cozzani et al. [7] based on empirical data resume, Equation 2

$$P_d = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{Y-5} e^{-x^2/2} dx \qquad (2)$$

In the formula, Y is the probabilistic unit of the time-expanding effect of the initial test (target device destruction); x is the integral variable. The atmospheric pressure vessel part of the formula for calculating the probability unit is

$$Y = 12.54 - 1.847 \ln t$$

$$\ln t = -1.128 \ln q(r) - 2.667 \times 10^{-5} V - 9.877$$

In the formula, t is the time without failure, s; q(r) is the heat flux received by the target at the center r of the fire source, kW/m^2; V is the equipment volume, m^3.

2.5. Bayesian posterior probability of pool fire domino effect

In the Bayesian rule, the posterior probability P(h|D) can be calculated by the prior probability (Eq. (3)). P(h|D) is proportional to P(h) and P(D|h) and inversely proportional to P(D) that the more likely to be observed when D is independent of h, the support of D for h. The smaller the degree [8]. According to the nature of the posterior probability in the Bayesian rule, the most contributing point to the domino effect can be determined by calculating the posterior probability of tank fire in the domino effect of the pool fire, and targeted control measures can be formulated. The posterior probability is

$$P(h|D) = (P(D|h)P(h)/P(D)) \qquad (3)$$

In the formula, P(h) is the probability of occurrence of event h; P(D) is the probability of occurrence of event D; P(D|h) is the prior probability of occurrence of event D that is the premise event of occurrence of event h; P(h|D) is the posterior probability corresponding to P(D|h).

3 conclusion

- Storage tank areas with different material or types of vessels can be analyzed in different steps. The Bayesian prior and posterior probabilities of the domino effect occurrence probability can be calculated on this basis. Furthermore the domino effect of the pool fire in the atmospheric pressure tank area can be inferred and the specific Bayesian network diagram can be given.
- According to the characteristics of the explosion of high-pressure storage tanks, the probability of accidents in adjacent tanks can be determined by drawing to achieve the purpose of simplific ation,once the high-pressure storage tank exploded and no clear in probability.
- According to the nature of the posterior probability in the Bayesian probability theory, combine d with the calculation formula of the posterior probability, thus the posterior probability of all d omino accident scenarios is compared so as to determine the best control point for the domino e ffect that should be applicable the specific control plans and solutions available throughout the a ccident chain.

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