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Fire Source Position Strategy for Chemical Plants Based on Image and Numerical Simulation Technology

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In order to ensure the safety of chemical plants, this paper analyzes the image and numerical simulation technology applied by chemical plants to position the fire source and carry out the fire protection. Actual researches and simulation computation are used in the analysis. The fire source position strategy for chemical plants based on image and numerical simulation technology is obtained. The image and numerical simulation technology can effectively manage fire spread, crowd evacuation and smoke control in fire.

1. Introduction

There are some risks in chemical plants, such as fires and other major safety accidents. With the development of modern science and technology, many relevant protective measures are carried out to prevent fires, including image and numerical simulation technology that is very common. The image and numerical simulation technology is to position, simulate and predict fires based on the computer technology. Its main working process is divided into physical simulation level, semi-physical simulation level, and experienced simulation level.

In order to verify the image and the numerical simulation technology, this paper analyzes the application effect in fire hazard of chemical factories. The analysis focuses on the fire source position strategy, because there are a lot of chemicals in chemical plants that cause fires could not be put off directly by water. Therefore, the best way is to locate and control the fire source.

2. Literature review

Information technology is the pillar industry in twenty-first Century, which has developed rapidly and played a very important role. And sensor technology is an important branch of information technology. Information technology is mainly the collection, transmission and processing of information. With the promotion of rapid development of microelectronics technology, the sensors are developing towards intelligence, high integration and smaller volume. Because of the widespread use of information in practical applications, there are many coordinate points and complex wring with wide range. Therefore, the new sensor network can not only collect receipts, but also transmit and process data. It becomes a whole structure, which is a new research content. This new sensor network will be widely used in traffic management, fire prediction and medical care and other occasions. Information is a whole content that includes the extraction, transmission and processing of information, then the function of the sensor is to acquire and perceive some external physical information.

With the continuous development of science and technology, as well as the fear of great damage to the fire, people have been forced to explore an effective way of monitoring and warning of fire. The search of fire source target is a typical target search problem. Wireless sensor technology and robot with temperature detection device are used to automatically search and track the trajectory of temperature diffusion and determine the location of the fire source, which has great application value in forest fire prevention. The characteristic of the fire source search is that the energy attenuation radius of the target fire source is short, which makes it difficult to quickly complete the tracking and positioning of the fire source target in a large area. For the detection of fire source in chemical plant, in the current research at home and abroad, from the principle of fire source positioning, the location of the fire source is mainly completed through collecting the

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information of the change of the physical and chemical properties in the process of formation and development. After analysis and research, the location of the fire source is determined. These principles are summarized as follows: the anomalous location of the temperature field; the location of the gas by the spontaneous combustion; through the electrical properties; through the change of the magnetic field after the spontaneous combustion. The principle of fire source positioning is studied both at home and abroad, but because of the complexity of the conditions and the research on the related mechanism, there is no real application at present.

In the fire research, the numerical simulation is a kind of effective research method with less investment, especially for the chemical plant fire. The field experiment investment is huge and the risk is great, it is easy to cause the non-control accident, so the numerical simulation method highlights its superiority. The numerical simulation of chemical plant fire is similar to other fire numerical simulation. It mainly includes regional simulation, field simulation and field network composite simulation technology. Delele and other researchers described three computational models used to study the effects of fire in a chemical plant. The chemical plant was regarded as a whole with the network model of chemical plant. The multi-dimensional CFD model was used to test the flow in the near fire source area. The results of this model highlighted a possible mitigation method for reducing the flow of combustion products. This would benefit the integration of the CFD model with the network model, because so far the boundary conditions for CFD were only an estimated or approximate value (Delele et al., 2016). Amalina and others discussed the basic strategy cited in the simulation package "FIRES", which was used to simulate ventilation during chemical plant fire. A chemical plant fire was used to simulate laboratory conditions, and the simulation results were compared with the experimental results (Amalina et al., 2017). Alkhalaf and Specht used a CFD program -CFD2000- to predict the smoke flow of two fires at zero inlet velocity. The Froude value was applied to the one-dimensional model to determine whether there would be adverse current. If the wind speed was greater than the critical wind speed, no counter-current would occur. In the experiment, only small and steady fire was studied, and the heat exchange of rock mass was not considered (Alkhalaf and Specht, 2017). Moinuddin and other researchers used the method of regional simulation to simulate the fire smoke movement in the chemical plant, grasp the law of fire smoke flow and the distribution of the smoke, and compare the experimental results with the simulation results. The feasibility of numerical simulation of the fire smoke movement in the chemical plant was also verified (Moinuddin et al., 2017). Wang and Wang divided the calculation model of 65 kinds of fire and smoke movement according to the different internal control systems in the reference area, and the simulation of fire smoke flow was divided into three parts according to the actual situation (Wang and Wang, 2016). Zhong et al. applied CFD software to calculate the flow and temperature distribution of the smoke flow in the chemical plant during the fire. In the process of simulation, there were several important key points, including the selection of fire model, the thermal radiation of the flue gas and the determination of the boundary conditions (Zhong et al., 2016). Kewlani and other researchers also used the Reynolds equation to simulate the turbulent flow of smoke in simulated chemical plant fires or building fires. The combination of field simulation results and the environment of the model were always the concern of the researchers, especially in the field of smoke flow field simulation. Virtual reality and the implementation of the technology and other aspects of the research were still being explored (Kewlani et al., 2016). Zhou and other researchers, based on the principle of computer binocular stereo vision technology, used a single eye CCD camera fixed at the end of the intelligent fire cannon with the intelligent fire gun to scan and shoot, and thus get the change of angle and displacement and so on. The coordinate information of the two-dimensional fire source image and the three-dimensional space coordinate letter were taken. In order to realize the automatic positioning function of the coordinates of the fire source of large space buildings (Zhou et al., 2016), the relationship between the information and the three-dimensional space positioning principle of the polar geometry scanning monocular CCD camera is established.

To sum up, in the above research work, the movement of flue gas, the flow and distribution of smoke flow and the influence of the fire when the chemical plant fires are mainly stimulated. And according to the principle of the computer binocular stereo vision technology, CCD is used to do an in-depth study of the intelligent fire gun to rotate scanning and filming. But the application of image simulation technology is very few. Therefore, based on the above research status, the location strategy of fire sources in chemical plant is focused on based on image and numerical simulation technology. The fire sources are located, fire prevention is implemented, and the fire source positioning strategy is obtained by practical research and simulation calculation. Thus the image and numerical simulation technology can effectively manage fire spread, crowd evacuation and smoke control.

3. Methods

3.1 Fire Burning Process

The fire burning process changes with time and is divided into five different stages, as shown in Figure 1.

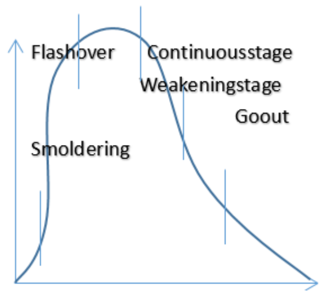

Figure 1: The five stage of the development of indoor fire

(1) Smoldering
This process features with the heat release and increasingly intense chemical reactions. The rate of energy generation, ventilation, cooling conditions of surrounding fuels and other factors affect the smoldering.
(2) Flashover
Fires are primarily determined by the specific type of fuels, surrounding environment, the availability of oxygen and other related factors. In this process, the temperature of the surrounding environment is generally very low and the scope of fire source is small, so this process is the best stage to escape from the fire.
(3) Continuous Stage
In this stage, the fire will spread to the whole interior quickly and generate a lot of combustible gas gathered on the roof. When the concentration of combustible gas breaks a certain restriction, it will quickly spray out. Studies have shown that if the indoor temperature rises to 500-600 ℃ or the thermal radiation of the floor is up to 15 to 20 kw / ㎡, it will enter into the continuous stage. The main factors that influence the occurrence of continuous stage are the size of space, opening area, heat release rate, ventilation condition, and etc.
(4) Weakening Stage
In this phase, the combustion heat release rate will maximize. The availability of oxygen affects the fuel burning. The indoor temperature will reach 700-1200 ℃ after fuels achieve full burning.
(5) Goout
Due to the decreasing of combustible materials, the rate of heat release will be increasingly lower and the burning activity will gradually weaken.

3.2 Large Eddy Simulation Technology of Image and Numerical Simulation Technology.

(1) Basic Thought of Large Eddy Simulation
The large eddy simulation (LES) is a turbulence number simulation between the direct numerical simulation and the RNAs. In order to simulate the turbulent flow, it is required that the calculation area should be large enough to contain the largest eddy in the turbulent motion. On the other hand, the scale of the computational grid should be small enough to distinguish the motion of the smallest eddy. Figure 2 shows the basic thought process of large eddy simulation.

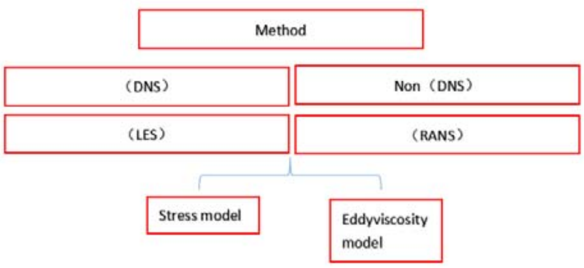

Figure 2: The basic thought process of large eddy simulation in

To achieve the large eddy simulation, there are two important links. One is to establish a mathematical filtering function. A large eddy motion equation is obtained by filtering the eddy which is smaller than that in the filtering function from the instantaneous motion equation of turbulence. The affect of filtered small eddy on the large eddy motion will be introduced into the additional stress through the movement in the large eddy flow field. This stress, like Reynolds stress, is called the grid scale stress. The mathematical model of this stress is called the Sub Grid Scale model, or SGS model.

(2) Large Eddy Flow Field Motion Equation

In the LES, the transient variable Φ can be divided into two parts by filtering functions: the average component Φ of the large scale is the variable after filtering, which is the part directly calculated in the LES. In the equation $\Phi = \int_X^\Phi G(x,x^1)dx^1$, where D is the flow area; x is the spatial coordinate in the actual flow region; x1 is the spatial coordinate after filtering; G(x, x^1)G is the filtering function which determines the scale of the eddy to be solved, that is the large and small eddies will be separated.

3.3 FDS Calculation Process

In this paper, FDS, the fire dynamic simulation software, is a numerical simulation research tool. Its application and operation flow charts are shown in Figures 3 and 4, respectively.

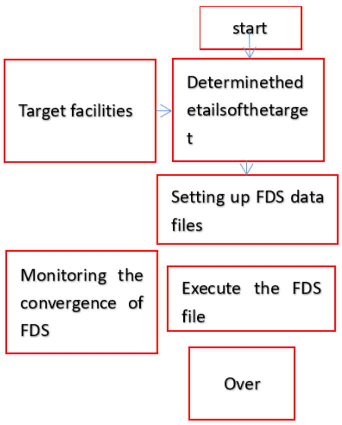

Figure 3: FDS application flow chart

3.4 Simulation Calculation of the Automatic Fire Extinguishing System's Operation Time

The current automatic sprinkler system is also started by the fume temperature, and its working principle is basically same as that of the thermal detector. There are many software is used to calculate the response time of the automatic sprinkler system, such as DETACT-QS, DETACT-T2, G-JET, HAD, JET, LAVENT, PALDET, TDISX, Fire Dynamics Tools (FDT), Fire Protection Engineering Tools (FPETools), SPEINK, etc. The paper forecasts the action time of the automatic sprinkler system. The calculation conditions and results are shown in Table 1.

Table 1: DETECTT2 calculation conditions and results

Project	shops
Ceiling height	3.2
Time response index (RTI) of sprinkler sprinkler	50 $m^{1/2}s^{1/2}$
Action temperature of sprinkler	68□
Spacing between sprinklers and sprinklers	3.0m
Ambient temperature	25□
The law of early development of fire	□α=0.04689
Start time of automatic sprinkler system	122.4s

3.5 Fire Source Position

It is assumed that the sixth fire zone has two functional areas 1 and 2. The functions of each region, fuels, areas and fire loads are shown in Table 2. The fuel types in these two areas are similar. Due to the 2 area is much bigger than, the area 2 is determined as the fire source area, namely the fire is positioned in the axes 11-15 and U-Y, considering the impact of the fire on the whole space, and following the principle of "credibility: the most adverse".

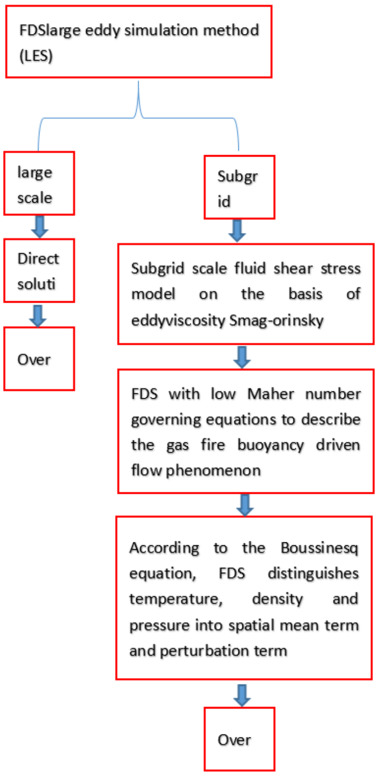

Figure 4: FDS operation flow chart

Table 2: Fire load in 6 functional areas of fire zone

region	function	Main combustibles	Fire load density (MJ/m2)	The measure of area(m^2)	Fire load
1	shops	Combustible object	480	281	134880
2	shops	Combustible object	480	933	447840

4. Results and Analysis

This paper analyzes the fire prevention, fire protection of steel construction, and the application of numerical simulation technology in the passive fire control.

Firstly, the passive fire control technology is to reasonably design the architectural spaces, carry out effective fire-resisting division measures in accordance with the requirements of fire prevention, and to make the combustion performance and the fire resistance rating of construction components, building materials, and decoration materials meet the requirements, ensuring the development and spread of the fire in the building's physical spaces can be effectively controlled within a small space and maintain for a long time, without causing more casualties and property losses. Currently, the passive fire control technology mostly used in the design of building fire protection is to maintain a certain fire protection spacing, set the fire resistance rating of construction components, building materials, and decoration materials, divide fire zones, create fire fighting and rescue conditions, provide other measures for fire-resisting divisions, and etc.

Secondly, the fire protection spacing is a necessary space between two buildings for fire fighting, personnel safety evacuation and heat radiation reduction. It is necessary to set a certain distance between buildings in order to prevent fire spreading among buildings. This will minimize the impact of radiant heat, avoid the burning of adjacent buildings, and provide necessary sites for evacuees and fire fighters.

5. Conclusions

The safety of personnel evacuation in different fire scenes is analyzed through comparing the available required safety egress time obtained by the fire simulation and the personnel evacuation simulation with the required safety egress time. The results show that when the automatic sprinkler system fails but the mechanical smoke extraction system is effective, it cannot guarantee the safe evacuation of all personnel.

When the automatic sprinkler system is effective but the mechanical smoke extraction system fails, it can basically guarantee the safe evacuation of all personnel. When both are effective, all personnel can be safely evacuated to safe areas.
The start-up time of automatic fire-extinguishing system is calculated by simulation. FDS physical model is established to simulate the safe evacuation time in a certain fire scene. FDS+Evac physical model is established to simulate the action time for evacuation, to verify the application of the numerical simulation technology in predicting the action time of the automatic fire-extinguishing system, fire development and spread, as well as the personnel evacuation time.
This paper analyzes the application of the numerical simulation technology in designing the fire prevention width, calculates a reasonable width for a convention center under an assumed fire scenario, compares with the theoretical calculation results to verify that the results of numerical simulation are in close agreement with the theoretical calculation, and finally determines that the convention center's fire prevention width is 10 meters.
With the advantages of FDS+Evac, both the spread of fire and the evacuation are simulated and calculated. The results show that products from the fire also can produce certain effects on the evacuation without affecting the safety of personnel, which increase the evacuation time.
FDS physical model is established to analyze the application of the numerical simulation technology in the fire protection of steel construction, determining that the convention center's fire prevention scope is below the second floor 10 meters.
Due to the limitation of objective conditions and the theoretical level, there are some limitations and shortcomings in understanding the application of numerical simulation technology, establishing models, analyzing data, and other aspects. For example, only a part of active and passive fire protection technologies are verified by the numerical simulation, while others are not analyzed deeply. In the simulation process, there are some errors in selecting some parameters and setting the boundary conditions compared with the actual situation. These errors are not analyzed.

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