Analysis of Influence of VOCs Diffusion on the Operation of Liquid Cargo Tank in Multi Berth Anchorage Based on CFD

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ABSTRACT

This paper mainly aimed at the study on the diffusion mechanism of VOCs on multi-berth anchorage oil tanker operations, analyzed the theory of diffusion mechanism of VOCs on multi-berth anchorage oil tanker operation and established the models of physical, mathematical and numerical on the diffusion simulation of VOCs. Fluent software had been used, the paper simulated the diffusion mechanism of VOCs on multi-berth oil tanker operations under different environmental conditions, just like leakage intensity, temperature and speed. Types of simulation results mainly included pressure nephogram and gas concentration diagram. By Analysising the influencing factors, finally we ensured the safety of oil tanker operations.

INTRODUCTION

In the mid-20th century period, with the rapid development of productivity, emissions of oil tanker operation such as Volatile Organic Compounds increased and spread rapidly and seriously affected the environment and people's health. Therefore, oil tanker spread out relatively more VOCs, in the process of operations, compared to the freighter and working ship. More likely to cause personnel
poisoning, air pollution, and even the risk of burning explosion, which attracted a
great deal of attention from all walks of life.

During the course of mooring, the safety of the tanker was mainly affected by
environmental factors, ship factors and human factors. But the research on marine
environmental conditions of port berth anchorage oil tanker operation was rarely
reported. Based on this, this paper studied the influence of environmental factors on
the VOCs diffusion in liquid cargo operation of anchorage tanker.

VOCSDIFFUSION THEORY OF LIQUID CARGO OPERATION IN MULTI
BERTH ANCHORAGE TANKER

Gas diffusion could be divided into three physical forms, namely, drift diffusion,
momentum diffusion and molecular diffusion. Because of the monsoon in different
degrees in the selected sea area, with the development of VOCs drift diffusion and
momentum diffusion, there were some potential risks such as air pollution,
personnel poisoning, VOCs combustion and explosion at the tanker operation of
multi berth anchorage tanker.

In this paper, three factors, the intensity of VOCs diffusion, the temperature of
sea area and the velocity of sea area were simulated respectively. We tried to find
the law of VOCs diffusion under the influence of the above three factors, so that
operators could avoid working under adverse natural conditions, thus reducing the
risk of accidents.

MODEL BUILDING FOR GAS DIFFUSSION SIMULATION

Physical Model

A prototype of floating production storage and offloading tanker was
constructed. FPSO system had wide deck area, strong bearing capacity and strong
ability against wind and wave. And it was easy to produce equipment layout and
very representative. As is shown in Fig.1,because the diffusion point source size
varies greatly during different operation periods, it is assumed that the size of the
diffusion source is constant and continues to diffuse into the computational region.

Figure 1. Model of floating production and offloading tanker.
Numerical Simulation Model

Based on the above physical model and mathematical model, due to the long time, high cost and safety risk of the actual ship test in this project, we modeled and simulated the Fluent in advance to prevent greater economic losses. A computational region model of size 2.4km * 2km was established according to the specific literature. The diffusion of VOCs during the loading and unloading operation of the five berth tanker, which is evenly distributed at every 400 meters and equal distances on the 2.4km production berth line, is examined. In this case, the diffusion source is assumed to be quadrilateral, and the dimensions near the deck are 20m*10m and spread continuously to the computational region. The schematic diagram is shown in figure 2.

![Figure 2. Sketch map of calculation area.](image)

FLUENT SIMULATION ANALYSIS

The key of Fluent simulation analysis is to show the distribution trend. For example, the different colors shown in the pressure cloud indicate different trends in the magnitude of pressure. Red represents a great value of pressure, which is the result of macroscopic view. The VOCs concentration profiles show different concentrations of VOCs. Red represents a large concentration of VOCs. It is only a trend. It does not indicate the size of the specific concentration.

Analysis of Influence of Diffusion Strength

In order to study the law of VOCs diffusion when the VOCs diffusion intensity changes, we make a combination of the intensity of the diffusion as shown in Table 1.
TABLE I. DIFFUSION STRENGTH COMBINATION.

| Diffusion Strength | Sea Temperature | Wind Speed | Wind Direction |
|--------------------|-----------------|------------|----------------|
| 0.6 m³/s           |                 |            |                |
| 1.2 m³/s           | 300K            | 5.8 m/s    | W              |
| 2.4 m³/s           |                 |            |                |

When the author uses Fluent software to simulate the process, the residual graph shows that the convergence is good. Due to the limitation of the space, the detailed residual maps are not listed in detail, and the latter is not repeated.

THE DIFFUSION STRENGTH IS 0.6 M³/S

![Figure 3. Pressure nephogram.](image1)

Figure 3. Pressure nephogram.  

![Figure 4. VOCs concentration distribution map.](image2)

Figure 4. VOCs concentration distribution map.

THE DIFFUSION STRENGTH IS 1.2 M³/S

![Figure 5. Pressure nephogram.](image3)

Figure 5. Pressure nephogram.  

![Figure 6. VOCs concentration distribution map.](image4)

Figure 6. VOCs concentration distribution map.
THE DIFFUSION STRENGTH IS 2.4M³/S

![Pressure nephogram](image1)

![VOCs concentration distribution map](image2)

**Figure 7. Pressure nephogram.**  **Figure 8. VOCs concentration distribution map.**

**IMPACT ANALYSIS**

From the above analysis of pressure nephogram, when the diffusion intensity is 0.6m³/s, the pressure distribution is even, and the pressure is larger when approaching the upper wind direction. With the increasing of VOCs diffusion intensity, the convection between the air above the point of diffusion and the VOCs discharged from the point source is strengthened. When the diffusion strength is 1.2m³/s and 2.4m³/s, the regional pressure is obviously higher than the diffusion strength, and the pressure distribution is obviously unstable at 0.6m³/s.

From the analysis of the above VOCs concentration profiles, the VOCs are continuously downward to the wind direction, and the VOCs concentration at the gas vent increases with the increase of the diffusion intensity. When the diffusion intensity is 0.6m³/s, the distribution of VOCs concentration is uniform, and the operation of the tanker is relatively safe. When the diffusion intensity is 1.2m³/s and 2.4m³/s, the distribution of the dangerous explosion concentration area is uneven, and the probability of the risk of oil tanker operation becomes larger.

**Analysis of Sea Temperature Influence**

According to the average temperature of the four seasons in the sea area, the representative 275K, 300K and 305K were selected to simulate the operation of the tanker in winter, spring and autumn and summer. Sea temperature combinations as shown in Table 2.

| Sea Temperature | Diffusion Strength | Wind Speed | Wind Direction |
|-----------------|--------------------|------------|----------------|
| 275K            | 0.6m³/s            | 5.8m/s     | W              |
| 305K            |                    |            |                |
THE SEA TEMPERATURE IS 275K

Figure 9. Pressure nephogram. Figure 10. VOCs concentration distribution map.

THE SEA TEMPERATURE IS 300K

Figure 11. Pressure nephogram. Figure 12. VOCs concentration distribution map.

THE SEA TEMPERATURE IS 305K

Figure 13. Pressure nephogram. Figure 14. VOCs concentration distribution map.
IMPACT ANALYSIS

From the above analysis of pressure nephogram, with the rising of sea area temperature, the influence of sea temperature on the division of pressure zone of VOCs diffusion layer is not very obvious. The greater the pressure near the upper wind, the greater the gas pressure. Therefore, in the actual operation, we should strengthen the inspection of the pressure around the operation vehicle, and strengthen the safety measures so as to ensure the safety of the operation of the tanker.

From the above VOCs concentration map analysis, with the rising temperature of the sea area, he impact on the concentration of VOCs is not very obvious. The basic trend unchanged. The higher concentration of VOCs reservoir moves to the lower wind direction, and the area of dangerous explosion concentration is the largest. It is necessary to strengthen the detection of the VOCs concentration around the operation oil tanker under the lower wind direction, so as to ensure the safety of operation.

Analysis of Wind Speed Influence in Sea Area

According to the monthly average wind speed in the sea area, three representative groups of wind speed are selected for simulation study. They are 5.8m/s, 6.3m/s and 7.2m/s respectively, and the wind speed combinations in the sea area as shown in Table 3.

| Wind Speed | Diffusion Strength | Sea Temperature | Wind Direction |
|------------|--------------------|-----------------|----------------|
| 5.8m/s     |                    |                 |                |
| 6.3m/s     | 0.6m³/s            | 300K            | W              |
| 7.2m/s     |                    |                 |                |

THE WIND SPEED IN THE SEA AREA IS 5.8M/S

Figure 15. Pressure nephogram.  Figure 16. VOCs concentration distribution map.
IMPACT ANALYSIS

From the analysis of the above pressure nephogram, the change of wind speed in the sea area has no obvious influence on the distribution of pressure nephogram. With the increase of wind speed in the sea area, the wind direction is always high and the berthing pressure is great. Therefore, it is necessary to strengthen the pressure detection around the upper wind direction tanker. This conclusion is basically consistent with the analysis of the sea temperature.

From the above analysis of VOCs concentration distribution, with the rising of wind speed in the sea area, the division of VOCs concentration layer is not very obvious, and the concentration of VOCs in the lower wind direction area is always large. Therefore, in the process of tanker cargo operation in multi berth anchorage, the concentration of VOCs around the lower direction tanker should be effectively strengthened. We should effectively strengthen the detection of the VOCs concentration around the tanker under the direction of the wind, and avoid dangerous area operations, thus ensuring the safety of personnel.
CONCLUSION AND PERSPECTIVE

Conclusion

In this paper, the physical model, mathematical model and numerical model of gas diffusion simulation were established by the VOCs diffusion theory of liquid cargo operation in multi berth anchorage tanker. The main contents of this paper were summarized as follows:

VOCS DIFFUSION THEORY OF LIQUID CARGO OPERATION IN MULTI BERTH ANCHORAGE TANKER

Through the analysis of the concept of gas diffusion and its influencing factors, it was concluded that there were drift diffusion and momentum diffusion in the process of loading and unloading liquid cargo at anchorage. According to the analysis of factors affecting gas diffusion, the model variables in this study were mainly VOCs diffusion intensity, sea area temperature and sea area wind speed.

MODEL BUILDING FOR GAS DIFFUSION SIMULATION

In this part, we selected the physical model, construct the mathematical model and simulate it. The contents of numerical simulation included physical modeling, VOCs diffusion coefficient, mesh generation, boundary condition setting and calculation model.

FLUENT SIMULATION ANALYSIS

In view of the actual situation of liquid cargo operation of multi berth tanker, Fluent software was used to simulate the VOCs diffusion process of multi berth tanker liquid cargo operation, and then comprehensive analysis and comparison of different impact parameters were carried out. Finally, it was concluded that the simulation results were in good agreement with the theoretical analysis.

Perspective

Because of the limitation of the author's level and time, the research in this thesis needs further study:

In this paper, a simplified assumption is made in the numerical simulation. It is assumed that there is no heat exchange between air and oil, and there is no comparison experiment of heat exchange.

Due to the lack of experimental conditions, the simulation method was adopted in this paper, so there was a certain deviation from the actual operation. In the future research process, we need to make a comparison between the experiment and simulation, so as to strengthen the persuasiveness of the research results.
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