Orthogonal Investigation of Benzene Blocking Performance for the Hazardous Chemical Containment Boom

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Abstract. Along with the accelerating process of economy, the shipping throughout of hazardous chemicals has been increasing. Once the hazardous chemical leakage happens, it will cause serious damage to water and marine life around the accident spot. The containment boom is usually used for chemical blocking or diverting. There are several factors which affect the performance of the containment boom such as the water flow velocity, the wind velocity, the wave and so on. In this paper, the performance of the containment boom for hazardous chemical blocking was investigated via a software package Flow-3D. An orthogonal experiment was designed to find out how the factors affect the performance of the containment boom. The simulation results reveal that the water flow velocity plays a dominant part in the boom blocking performance.

1. Introduction

Chemical is an important kind of raw materials for industry. With the rapid development of the domestic economy, transportation of hazardous chemical is becoming more often than ever before. And this will bring leakage risk of the hazardous chemical. It is urgent to deal with the chemical leakage. In recent years, studies [1-4] were carried out to evaluate the behavior of different chemicals after the spill and the emergency response measures for different type of chemicals.

During the handling of chemical spill or leakage accident, the containment boom is usually used for the chemical blocking or diverting. Conditions such as the flow velocity, the tide height, boom characteristics, etc. affect the performance of the containment boom [5]. Thus, it is quite necessary to find out the influences of conditions on the containment boom (Figure 1).

In this paper. The software package Flow-3D was chosen to carry out the chemical blocking performance simulation of the containment boom. Orthogonal experimental design was conducted to find out how conditions affect the performance of the containment boom. The results show that the water flow velocity greatly affects the chemical blocking performance of the containment boom.

Figure 1. The containment boom

2. Simulation settings and orthogonal simulation design

The containment boom is used for the chemical blocking or diverting to certain areas for further treatment. In order to analyze the performance the boom, simplifying approach was conducted for the boom shown in Figure 2. In this paper, the boom height refers to the height of the boom whose part is under the water.
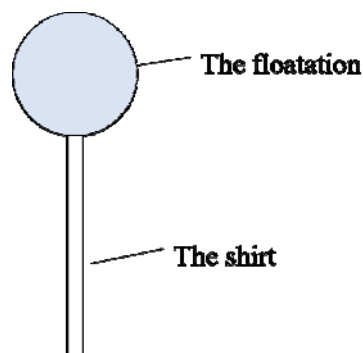

Figure 2. The structural diagram of the containment boom

The thickness of the shirt is 1 centimeter. The diameter of the floatation is 0.55 meter. During simulations, the size of the mesh near the boom is 0.01m in length and 0.01m in depth. The size of mesh for other calculation area is 0.02m in length and 0.02m in depth show in Figure 3.
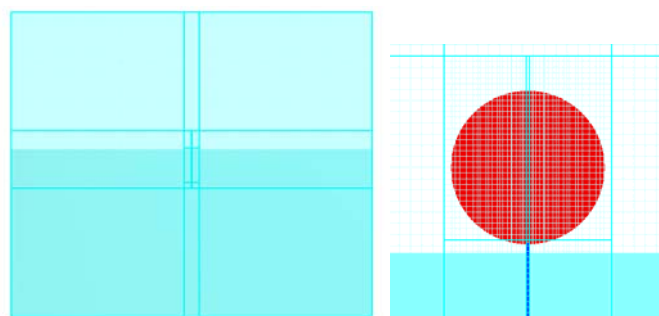

Figure 3. The mesh setting for the calculation area

In simulations, the calculation area of this study is 300 meters in length and 6 meters in depth. In the calculation area, 20 tons of benzene was placed 100 meters away from the boom.

Table 1. The orthogonal setting of different parameters

case	Water flow velocity (m/s)	The boom height (m)	Wind velocity (m/s)	Wave height (m)
1	0.5	0.6	5	0.25
2	0.5	0.8	10	0.5
3	0.5	1.0	15	1.0
4	1.0	0.6	10	1.0
5	1.0	0.8	15	0.25
6	1.0	1.0	5	0.5
7	1.5	0.6	15	0.5
8	1.5	0.8	5	1.0
9	1.5	1.0	10	0.25

There are several factors which affect the blocking performance of the containment boom. In this paper, the water flow velocity, the boom height, the wind speed, and the wave height were chosen as orthogonal parameters. And the orthogonal design was shown in Table 1.
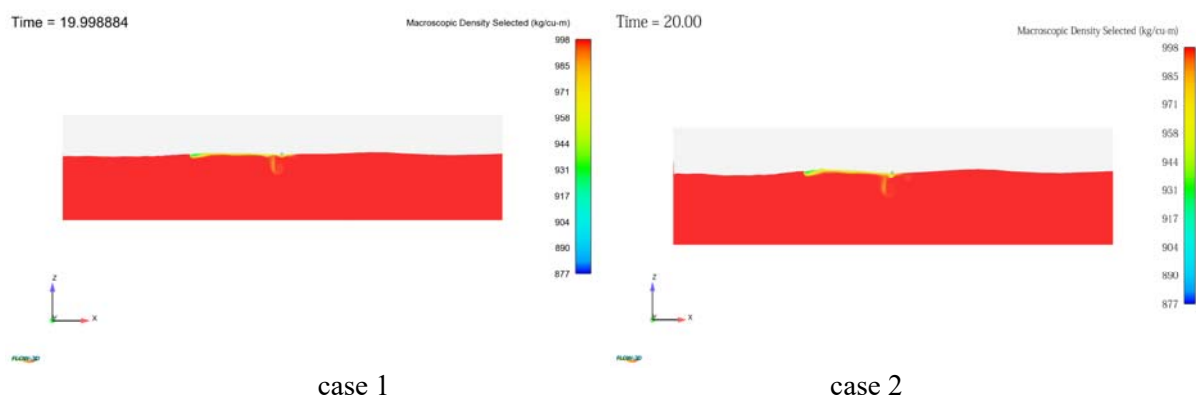
3. Results and Discussion

In order to evaluate the performance of the boom for chemical blocking, the escape quantity which means the quantity of benzene escapes under the containment boom was introduced. The less the escape quantity is, the better the performance of the containment boom is. The escape quantity at the same simulation time of different conditions were used for comparison.

Figure 4 and Table 2 shows the results under nine different conditions at the simulation time of 20 seconds. It can be concluded that the flow velocity greatly affects the blocking performance of the containment boom. When the velocity increases, more chemical of benzene will escape from the bottom of the shirt.

Through the statistics obtained from the simulation and the range analysis, the priority of the parameters which affects the blocking performance were the water flow velocity, the wind velocity, the wave height and the boom height.

Table 3 shows the blocking performance of the boom at different conditions. The results manifests the same trend as the results in Table 2. Conclusions can be drawn that the water flow velocity affects the blocking performance most   and then and the boom height has the least influence on the boom blocking performance.
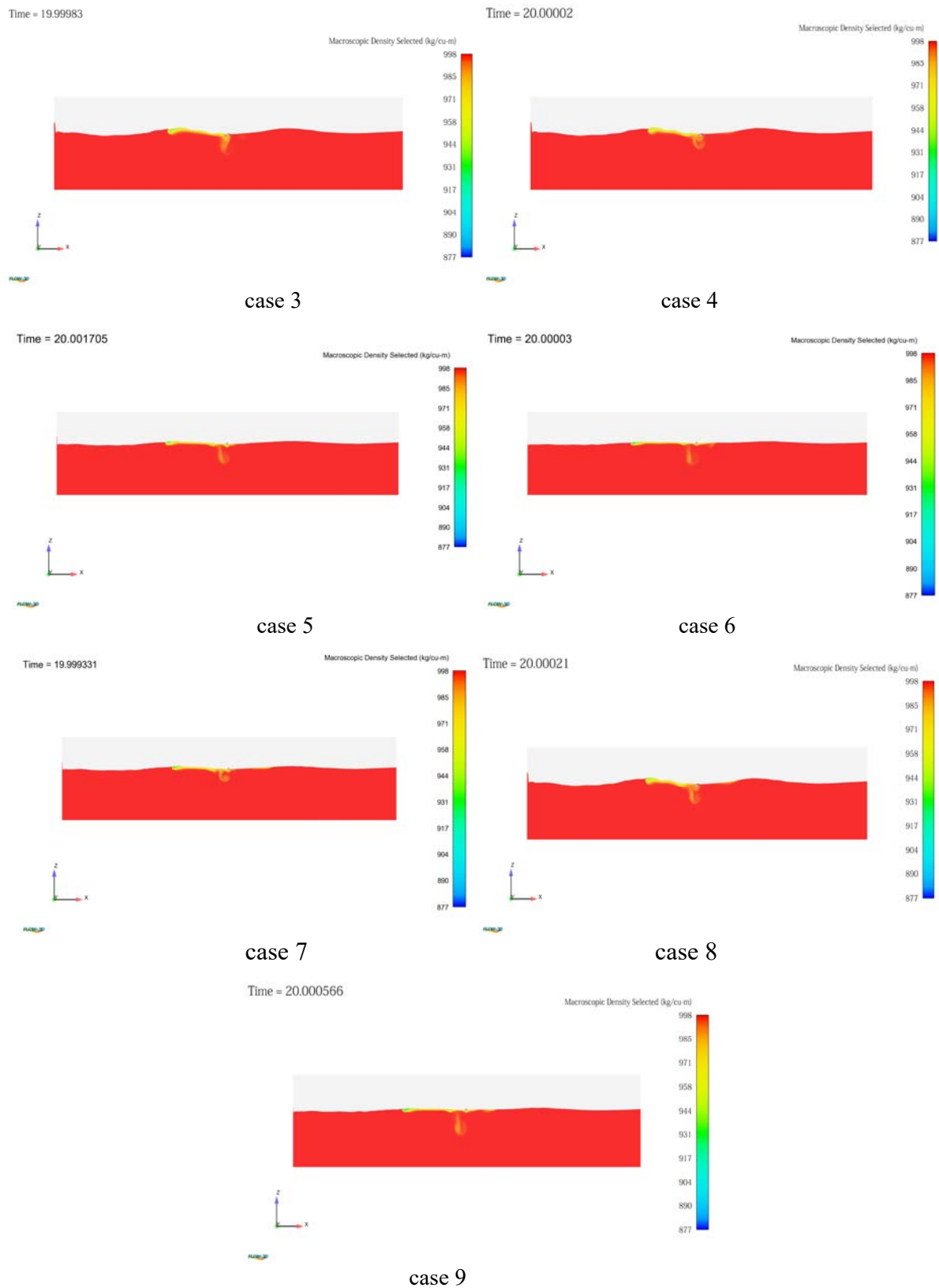

case 1   case 2

case 3

case 4

case 5

case 6

case 7

case 8

case 9

Figure 4. Results under nine different conditions at time of 20 seconds

Table 2. Blocking performance of the boom at different conditions of 20s

case	Water flow velocity (m/s)	Boom height (m)	Wind velocity (m/s)	Wave height (m)	Escape quantity of benzene (%)
1	0.5	0.6	5	0.25	6.80
2	0.5	0.8	10	0.5	5.80
3	0.5	1.0	15	1.0	3.60
4	1.0	0.6	10	1.0	4.80
5	1.0	0.8	15	0.25	62.7
6	1.0	1.0	5	0.5	8.70
7	1.5	0.6	15	0.5	17.4
8	1.5	0.8	5	0.25	8.40
9	1.5	1.0	10	1.0	11.2
k1	16.2	29.0	23.9	77.9	
k2	76.2	76.9	21.8	31.9	
k3	37.0	23.5	83.7	19.6	
$\overline{K1}$	5.40	9.70	8.00	26.0	
$\overline{K2}$	25.4	25.6	7.30	10.6	
$\overline{K3}$	12.3	7.80	27.9	6.50	
Range	20.0	17.8	20.6	19.5	

Table 3. Blocking performance of the boom at different conditions of 50s

case	Water flow velocity (m/s)	The boom height (m)	Wind velocity (m/s)	Wave height (m)	Escape quantity of benzene (%)
1	0.5	0.6	5	0.25	6.80
2	0.5	0.8	10	0.5	5.80
3	0.5	1.0	15	1.0	3.60
4	1.0	0.6	10	1.0	4.80
5	1.0	0.8	15	0.25	62.7
6	1.0	1.0	5	0.5	8.7
7	1.5	0.6	15	0.5	17.4
8	1.5	0.8	5	0.25	8.40
9	1.5	1.0	10	1.0	11.2
k1	38.7	47.5	45.7	114.9	
k2	125.7	119.2	48.1	49.9	
k3	56.7	54.4	127.3	56.3	
$\overline{K1}$	12.9	15.8	15.2	38.3	
$\overline{K2}$	41.9	39.7	16.0	16.6	
$\overline{K3}$	18.9	18.1	42.4	18.8	
Range	29.0	13.9	27.2	21.7	

4. Conclusion

Hazardous chemical leakage has become a serious problem. It will bring water pollution and further cause ecological crisis. The containment boom is an important kind of emergency handling equipment. In this paper. Various parameters were chosen to investigate the performance of the containment boom for hazardous chemical blocking via a software package Flow-3D. Orthogonal experiment design was introduced and according to the simulation result, the priorities which affects the boom blocking performance were find out. It is shown that the water flow velocity has the greatest influence on the blocking performance. Attention must be paid when the boom is chosen to deal with the chemical leakage.

References

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