Numerical simulation study on diffusion of temperature drainage in wide and shallow water in a refinery integration project

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Abstract. The numerical simulation of tidal current field in wide and shallow waters (Naochao River) of Caofeidian industrial zone is carried out by using a two-dimensional hydrodynamic model, taking the discharge problem of temperature and drainage in a refinery integration project as an example. Taking the tidal current field as the hydrodynamic condition of the temperature drainage transport simulation, the concentration distribution of the temperature drainage in the receiving water area was predicted by using the two-dimensional convection-diffusion model of the temperature drainage, and the change of the temperature rise line and its influence were analyzed. The results showed that the water area affected by temperature rise in winter and summer were 0.28km^2 and 0.35km^2, respectively, when the project was discharged separately. The existing temperature displacement of China Resources Power Plant in the superposition area is: 19.1km^2 in winter and 1.64km^2 in summer under the influence of temperature rise. By analyzing the influence degree of wide and shallow water (Naochao River) drainage outlet on temperature rise, the conclusion that the layout of drainage outlet should be further optimized is given.

1 INTRODUCTION

In recent years, with the construction of coastal nuclear power plants and thermal power plants, a large number of thermal drainage into the coastal waters, so that the problem of Marine thermal pollution gradually prominent. The centralized discharge of cooling water will not only heat up the surrounding water and cause thermal enrichment, but also affect the water quality and thus have a huge impact on the water ecological environment. Since the temperature drainage will cause the water intake to heat up synchronously, the location of the discharge outlet will also greatly affect the unit efficiency [1-3].From the beginning of 1980s, many domestic scholars began to conduct the simulation research of temperature drainage. Li Yanchu [4] used ADI difference method to conduct numerical simulation on the influence of temperature drainage of Punyu Power plant on the nearby sea area. Hua Zulin et al. [5] conducted numerical and physical model studies on the temperature drainage of two large power plants in the Yangtze River Estuary, and predicted the influence range of temperature drainage and temperature rise distribution. Liu Haicheng et al. [6] applied MIKE21-FM module and studied the diffusion law of temperature drainage in Aceh power plant in Indonesia under the condition of long period power, taking into account the long-period power factors such as ocean current and monsoon. Yan Bing et al. [7] adopted unstructured grids to compare the influences of different extraction and drainage outlet positions on the temperature drainage range and temperature rise of water intake.

Taking the discharge of thermal drainage in Natohe River of Tangshan Xuyang refining and Chemical integration project in Caofeidian as an example, this paper adopts a two-dimensional tidal current and temperature diffusion model to simulate the diffusion range of thermal drainage in shallow wide water area after the construction, which provides a reference for the optimization of the layout of the drainage outlet.

2 MATERIALS AND METHODS

2.1 Overview of Mat Research Area

Tangshan Xuyang Petrochemical Co., LTD. 15 million tons/year refinery integration project is located in the south central caofeidian Industrial Zone, Tangshan city, including the main project, environmental protection project, storage and transportation project, public works, corresponding supporting facilities and supporting projects. The seawater dc cooling system is used to cool the coolers in oil refining and chemical plants, and the seawater after heat exchange is directly discharged back into the sea. According to the cooling system requirements of the process unit, 201,900 m /h seawater drainage scale is designed.

After the discharge of warm drainage, the Shihua Xihe route is used, and the Shihua Xihe is widened and deepened as the open drainage channel of this project.

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2.2 Numerical Simulation

According to the research purpose, the integrity of hydrological data and the requirements of model calculation, the computational domain is the sea area 50km from east to west and 30km from north to south with Caofeidian industrial Zone as the center. The square grid is used for calculation, and the grid space step is 120m. The area near the project is encrypted, and the encrypted grid step is 40m.

The water flow model and water temperature diffusion model were used to predict the influence of temperature drainage on water environment.

2 - dimensional tidal current and basic equations of diffusion:

$$\frac{\partial h}{\partial t}+\frac{\partial (Hu)}{\partial x}+\frac{\partial (Hv)}{\partial y}=0 \quad (1)$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}-fv= -g\frac{\partial \zeta}{\partial x}+\frac{\partial}{\partial x}(N_x\frac{\partial u}{\partial x})+\frac{\partial}{\partial y}(N_y\frac{\partial u}{\partial y})-f_b\frac{\sqrt{u^2+v^2}}{h+\zeta}u \quad (2)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+fu= -g\frac{\partial \zeta}{\partial y}+\frac{\partial}{\partial x}(N_x\frac{\partial v}{\partial x})+\frac{\partial}{\partial y}(N_y\frac{\partial v}{\partial y})-f_b\frac{\sqrt{u^2+v^2}}{h+\zeta}v \quad (3)$$

ζ :Relative to the water level of a certain base plane (m);

h :Water depth relative to a certain base surface (m);

N_x :Viscosity coefficient of flow turbulence in x direction (m2 / s);

N_y :Y - direction flow turbulent viscosity coefficient (m2 / s);

f :Coriolis coefficient

f_b :Bottom friction coefficient

Water temperature diffusion pattern :

$$\frac{\partial hT}{\partial t}+\frac{\partial huT}{\partial x}+\frac{\partial hvT}{\partial y}=K_x\frac{\partial^2 (hT)}{\partial x^2}+K_y\frac{\partial^2 (hT)}{\partial y^2}+M-K_sT \quad (4)$$

T： Temperature difference;

K_x 、 K_y： Are the diffusion coefficients in the x and Y directions respectively. In this simulation, the diffusion coefficient is set as 5.

Ks： Comprehensive heat dissipation coefficient;

M： Warm water discharge term

Model prediction is mainly carried out when a port pond is connected to The Natocho River, and the influence of temperature emission is compared when a port pond is closed to the Natocho River (current situation). Then add the influence of China Resources power plant temperature emissions for comparison.

Under the condition of constant heat transfer area and heat transfer intensity, 12 pumps are set up in the seawater pumping station. In summer, the seawater circulation pump was opened 10 times and prepared 2 times. The circulation volume of seawater was 201,973 m /h (total 56.11m /s), and the temperature of seawater was 10℃. In winter, the seawater circulating pump was opened 6 times and prepared 6 times. The seawater circulating capacity was 1442.66 million m /h (40.08m /s in total), and the temperature rose to 14℃. The diffusion of the outlet is analyzed and calculated, and the diffusion influence during the whole tidal period is calculated.

Table 1. The simulation calculation scheme of temperature and drainage diffusion

Season	tidal type	drainage discharge (m^3/s)	drainage temperature rise (℃)
Summer	full tide	56.11	10
Winter	full tide	40.08	14

3 RESULTS AND DISCUSSION

3.1 The temperature rise field in the case of separate discharge

Figure 1~2 and Table 2 show the results of temperature rise field in the case of separate discharge of temperature drainage in Xuyang refinery integration project. After the predicted discharge of warm water through the outlet, the longitudinal diffusion distance of the 4℃ temperature rise line at the full-tide outlet in summer is about 1km, the transverse diffusion distance is about 0.35km, and the maximum envelop area is 0.28km. In winter, the longitudinal diffusion distance of the 4℃ temperature rise line at the full-tide outlet is about 1.1km, the transverse diffusion distance is about 0.31km, and the maximum envelope area is 0.35km.

Table 2. Maximum tidal temperature rise envelope area of drain (km)

Season	Wave type	1℃~2 ℃	2℃~3 ℃	3℃~4 ℃	>4℃
Summer	Full tide,	12.62	2.76	0.29	0.28
Winter	Full tide,	10.93	3.18	0.36	0.35

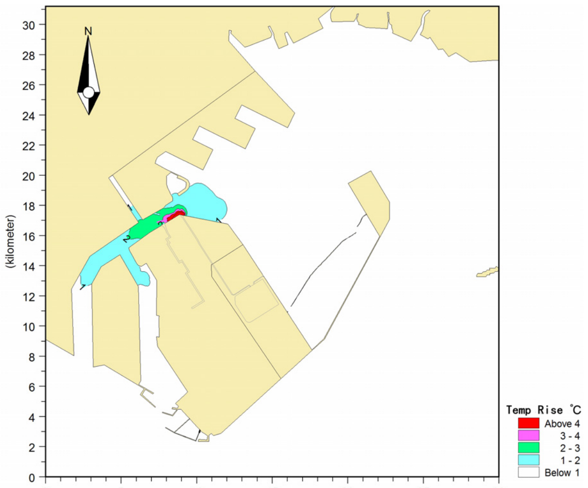

Figure 1. Envelope diagram of Maximum temperature Rise (summer)

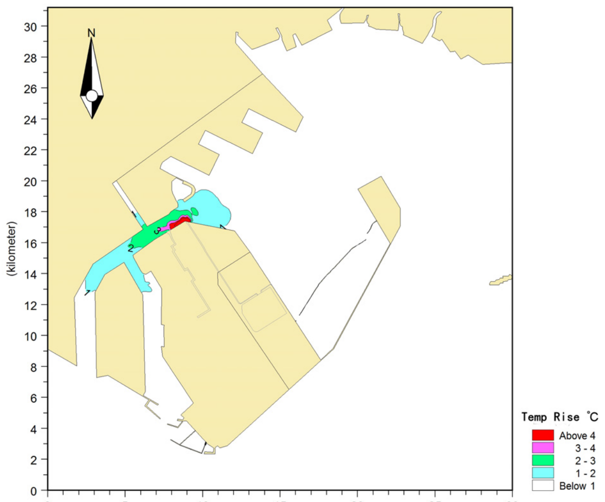

Figure 2. Envelope diagram of Maximum temperature Rise (winter)

3.2 The temperature rise field in the case of superimposed built projects

Figure 3~4and Table 3 for the results of the temperature rise field superimposed on the constructed China Resources project. The self-built open drainage channel of China Resources Power Plant enters the Naochaohe River after the thermal drainage channel of the power plant. The discharge position is located between No.2 Bridge and Caonan Railway. The coordinate is (118°28'26.75"E, 39°02'41.45"N).

In the prediction process, the displacement in summer was 82.4m /s, and the temperature rise of the given drainage was predicted to be 7.94℃. The displacement in winter is 50.9m/s, and the temperature rise of the given drainage is predicted to be 10.25℃.

Considering that China Resources Power Plant in Caofeidian Island also discharges warm water into The Natohe River, in order to analyze the superposition effect of warm water discharged by the project outlet and warm water discharged by China Resources Power Plant, the influence of temperature rise of the project outlet and China Resources Power Plant outlet on the surrounding waters is simultaneously considered in this forecast.

After superimposing the temperature discharge strength of China Resources Power Plant, after the warm water is discharged through the thermal discharge outlet of this project, the influence area of temperature rise exceeding 4℃ will be superimposed, no matter in summer or winter. The maximum envelopment area of temperature rise above 4℃ at the full-tidal discharge outlet in summer is 1.91km. In winter, the maximum envelop area of 4℃ temperature rise at the full-tide outlet is 1.64km.

Table 3. Maximum tidal temperature rise envelope area at simultaneous discharge (km^2).

Season	Wave type	1℃~ 2℃	2℃~ 3℃	3℃~4 ℃	>4℃
Summer	Full tide,	14.56	7.70	9.50	1.91
Winter	Full tide,	12.69	6.62	7.75	1.64

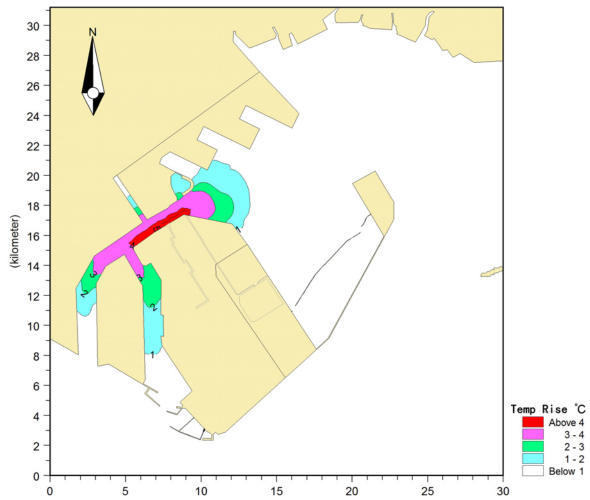

Figure 3. Envelope diagram of Maximum temperature Rise (summer)

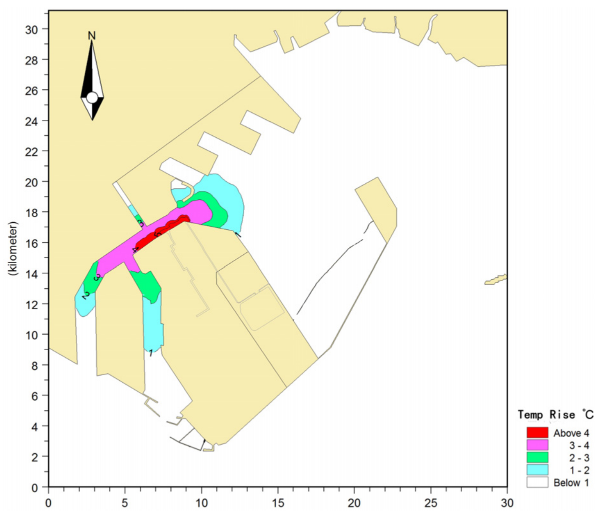

Figure 4. Envelope diagram of Maximum temperature Rise (winter)

4 CONCLUSION

In the case of separate discharge, the water body areas affected by temperature rise in winter and summer are $0.28km^2$ and $0.35km^2$, respectively.

After the existing temperature displacement of China Resources Power Plant in the superposition area, the water area affected by temperature rise in winter and summer is $19.1km^2$ and $1.64km^2$, respectively.

The Caofeidian industrial zone, weaker in the tidal river flow condition, the diffusion conditions are relatively poor, superposition existing China resources power plant temperature displacement HouDong and summer temperature scope change is very big, need to further optimize the location of the drain, or from the perspective of circular economy and regional LNG terminal as far as possible the use of circulating water temperature to reduce the displacement of the combination of emissions.

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