Research Article

Dynamic Model and Numerical Simulation of Maximum Turbidity Zone Formation in River Inlet

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1.Introduction

The estuary of a river can be seen as a relatively free and partially closed coastal body. It is connected to the ocean and is a transitional zone of rivers, which contains processes from land to sea and from fresh water to salt water. The estuary is one of the most productive natural habitats in the world and carries a large number of sediments due to natural factors such as changes in runoff and tides. Therefore, many coastal areas with river estuaries have become the most densely populated areas in the human population. In this paper, the RSM (Reynolds stress model) turbulence model and the PID (proportional integral derivative) algorithm are successfully used to simulate the dynamic model and for the numerical simulation of the formation of turbidity maximum zone in the estuary, which provides a theoretical basis for the follow-up of the similar research studies.
interest among domestic and foreign researchers [16]. At present, the related research work is mainly carried out from the following aspects. Some scholars have studied the research methods of hydrodynamic problems [17]. In the theoretical study, under certain conditions, the activity of upper water in shallow water area is very regular. At the same time, the activity of the upper water affects the fluid in the lower sediment and is penetrated by the two-fluid model [18, 19]. The researchers introduced longitudinal irregularity into the model, refined mud in the multilayer structure, and studied laminar flow sediment. In the aspect of experimental research, researchers from the research institute have completed the experimental research on the interaction between waves and sediments [20, 21]. In the process of wave attenuation and sediment transport, scholars have observed the final results under different conditions [22]. In the aspect of numerical simulation, some researchers use the numerical simulation method to study the wave motion under the action of waves and use numerical simulation method to study the submarine flow with a lot of soil [23, 24]. A finite difference method is used to calculate the two-layer structure of a viscous fluid system under pulsating action [25]. Generally speaking, the numerical study of free surface water sediment interaction in estuaries is rarely applied [26].

In this paper, the RSM turbulence model and the PID algorithm are used to study the dynamic model and numerical simulation of the formation of turbidity maximum zone in the estuary. The research work of these two aspects has been completed. The research is divided into three parts. Firstly, the multiresolution mesh subdivision model of the gradient divergence model itself, the stability of the turbulence maximum zone in digital estuary is established. Secondly, the RSM turbulence model is optimized by PID algorithm. Finally, the simulation calculation is carried out and good results are obtained.

2. Methodology

2.1. RSM Turbulence Model. The RSM turbulence model is often used to solve the Reynolds pressure for the second-order moment turbulent flow equation, as shown in Figure 1 [27]. In the RSM turbulence model, the constant of an equation is \( \frac{u_j'u_j}{\mu} \). This constant is mainly used to further improve the accuracy of the Reynolds pressure solution for the second-order moment turbulent flow equation [28]. By setting different \( \frac{u_j'u_j}{\mu} \) values, the purpose of precisely adjusting the fluctuation coefficient of the flow equation of the second-order moment turbulent flow is achieved [29] so that the Reynolds pressure of the flow Equation of the second-order moment turbulent flow can be more accurately obtained in the calculation process [30]. It is worth noting that there are many unstable factors in the flow equation of the second-order moment turbulence. These unstable factors make the calculation result of the second-order moment turbulent flow equation biased, so some effective measures must be taken to close the flow equation [31].

The RSM turbulence model mathematical calculation equation is as follows, and the obtained outputs are shown in Figure 2:

\[
\frac{\partial}{\partial t}(\rho u_j'u_j') + \frac{\partial}{\partial x_k}(\rho u_k'u_j') = -\frac{\partial}{\partial x_k}[p(t' u_j'u_j') + p(\delta_k u_j' + \delta_j u_k') + \frac{\partial}{\partial x_k}(\mu(t' u_j'u_j'))
\]

\[
\text{D}_{T,ij} = \text{P}_{ij} - 2\nu(t' u_j'u_j') - \rho \beta(u_j'u_j' + u_j'u_j')
\]

\[
\text{F}_{ij} = 2\nu(t' u_j'u_j') + \nu(t' u_j'u_j' + t' u_j'u_j')
\]

In equation (1), only \( D_{T,ij}, G_{ij}, \varphi_{ij}, \) and \( e_{ij} \) need to establish a corresponding mode to close the aspect, and variables \( C_{ij}, D_{L,ij}, P_{ij}, \) and \( F_{ij} \) do not need to sealing treatment.

According to the RSM turbulence model, the following model of gradient divergence can be established:

\[
D_{T,ij} = C_{ij} \frac{\partial}{\partial x_k}(\rho \frac{k u_k u_k}{\epsilon} \frac{\partial t' u_j'}{\partial x_i}).
\]

However, due to the existence of many uncertainties in the gradient divergence model itself, the stability of the equation is not satisfactory. Therefore, the equation is simplified as follows:

\[
D_{T,ij} = \frac{\partial}{\partial x_k}(\frac{\mu_k}{\sigma_k} \frac{\partial t' u_j'}{\partial x_i}).
\]

The simplified equation can be obtained using plane shear flow.

After obtaining the \( \sigma_k \) value, the linear stress-strain \( \varphi_{ij} \) value in the equation can be further obtained:

\[
\varphi_{ij} = \varphi_{ij,1} + \varphi_{ij,2} + \varphi_{ij,w},
\]
Figure 1: RSM turbulence model diagram.

Figure 2: Continued.
In equation (4), the variable $\varphi_{ij,1}$ is mainly used to express the slow pressure strain term, the variable $\varphi_{ij,2}$ is mainly used to express the fast stress-strain term, and the variable $\varphi_{ij,3}$ is mainly used to represent the wall reflection term. The variables in the above equation are calculated as follows:

The calculation equation for the slow pressure strain item $\varphi_{ij,1}$ is as follows:

$$\varphi_{ij,1} = -C_1 \rho \frac{\varepsilon}{k} \left[ u_i' u_i' - \frac{2}{3} \delta_{ij} k \right].$$  \hspace{1cm} (5)$$

The calculation equation for the stress-strain item $\varphi_{ij,2}$ is as follows:

$$\varphi_{ij,2} = -C_2 \left[ (P_{ij} + F_{ij} + G_{ij} - C_{ij}) - \frac{2}{3} \delta_{ij} (P + G - C) \right].$$  \hspace{1cm} (6)$$

Among them, $P_{ij}$, $F_{ij}$, $C_{ij}$, and $G_{ij}$ are given in equation (6). Moreover, $P = 1/2 P_{kk}$, $G = 1/2 G_{kk}$, and $C = 1/2 C_{kk}$.

The calculation equation of the wall reflection term $\varphi_{ij,3}$ is more complicated than the calculation equation of the slow pressure strain term $\varphi_{ij,1}$ and the calculation equation of the fast stress-strain term $\varphi_{ij,2}$. The specific calculation equation is as follows:

$$\varphi_{ij,3} = C_I^T \left( u_i' u_m' \delta_{ij} - \frac{3}{2} u_i' u_j' \delta_{ij} - \frac{3}{2} u_j' u_i' \delta_{ij} \right) \frac{k^{3/2}}{C_0 e d}$$

$$+ C_2 \left( \frac{\varepsilon}{k} \left[ \varphi_{km,2} n_k n_m \delta_{ij} - \frac{3}{2} \varphi_{km,2} n_i n_j - \frac{3}{2} \varphi_{km,2} n_j n_i \right] \right) \frac{k^{3/2}}{C_0 e d},$$  \hspace{1cm} (7)$$

where $n_k$ is mainly used to represent a unit in the wall and $d$ is the distance to the wall.

The calculation equation for the variable $G_{ij}$ is as follows:

$$G_{ij} = \beta \frac{\mu_t}{\rho Pr_t} \left( \frac{\partial T}{\partial x_j} + \frac{\partial T}{\partial x_i} \right),$$  \hspace{1cm} (8)$$

where the variable $Pr_t$ is mainly the actual Prandtl number used to represent turbulence. In general, the value of $Pr_t$ is mainly 0.85. The variable $\beta$ is used to represent the thermal expansion coefficient of turbulent flow. Turbulence in the ideal state can be calculated directly by using the following equation:

$$G_{ij} = \mu_t \frac{\rho}{Pr_t} \left( \frac{\partial \rho}{\partial x_j} + \frac{\partial \rho}{\partial x_i} \right).$$  \hspace{1cm} (9)$$

The calculation equation for the divergent tensor $\epsilon_{ij}$ is as follows:

$$\epsilon_{ij} = \frac{2}{3} \delta_{ij} (\rho \varepsilon + Y_M).$$  \hspace{1cm} (10)$$

In the above equation, variable $Y_M = 2 \rho \varepsilon M_t^2$ belongs to a diffusion term, so the actual calculation equation of its trickle term is as follows:

$$M_t = \sqrt{\frac{k}{a}},$$  \hspace{1cm} (11)$$

where the variable $a$ is mainly used to express the speed of sound. The ideal turbulent divergence rate $\varepsilon$ can be calculated directly by using the following equation $k - \varepsilon$:

$$\frac{\partial}{\partial t} (\rho \varepsilon) + \frac{\partial}{\partial x_i} (\rho \varepsilon u_i) = \frac{\partial}{\partial x_j} \left[ \left( \mu + \frac{\mu_t}{\sigma_\varepsilon} \right) \frac{\partial \varepsilon}{\partial x_j} \right]$$

$$+ C_{\alpha 2} \left( P_{ii} + C_{\alpha 3} G_{ii} \right) \frac{\varepsilon}{k} - C_{\alpha 2} \frac{\varepsilon^2}{k}. $$  \hspace{1cm} (12)$$

The calculation equation for the eddy viscosity coefficient $\mu_t$ is as follows:

$$\mu_t = \rho C_{\mu} \frac{k^2}{\varepsilon}.$$  \hspace{1cm} (13)
2.2. PID Algorithm. As early as in the 1930s, researchers proposed PID algorithms. After years of development, their practical application in industrial control has been quite abundant. Because of its relatively simple organizational structure, it is easy to improve. It is adaptable to all kinds of complicated situations. The related supporting control methods are also very efficient. In the process of industrial control, there are a lot of factors that will affect it [14]. The control process is adjusted at any time according to the actual situation, and the supporting control parameters are constantly changing, so it is very suitable to use the PID algorithm to control it, and the PID development process is also relatively easy. In the process of development, the parameters can be changed at any time according to the actual situation, which shows a very good flexibility, and it can adapt to any excessively redundant, as shown in Figure 3 [15].

The PID algorithm is a linear regulator. By linear combination, this regulator constitutes the control quantity by the ratio (P), integral (I), and derivative (D) of the control deviation \( e = r - y \), which is composed of the set point \( r \) of the system and the actual output value \( y \). Therefore, it is abbreviated as PID algorithm. The simulation PID control law in the continuous control system is

\[
u(t) = K_p \left[ e(t) + \int_0^t e(t)\,dt + T_D \frac{de(t)}{dt} \right], \tag{14}
\]

where \( u(t) \) is the output of the algorithm, \( e(t) \) is the deviation of the system’s given quantity and output, \( K_p \) is the proportional coefficient, \( T_I \) is the integral time constant, and \( T_D \) is the differential time constant. The corresponding transfer function is

\[
G(s) = K_p \left( 1 + \frac{1}{T_I s} + T_D s \right). \tag{15}
\]

The functions of the proportional regulator, integral regulator, and differential regulator are as follows. Firstly, the proportional regulator: the proportional regulator is to prevent the control parameters from deviating during the control process, thus causing the control error to occur [16]. If a control error occurs in the actual control process, the proportional regulator controls and adjusts according to the corresponding principle to minimize the deviation [17]. Secondly, proportional-integral regulator: in the process of proportional adjustment, there will be a static difference [18]. In order to compensate for the influence of the control caused by the static difference, a proportional-integral regulator is required for adjustment. It adjusts the control quantity by the deviation, and the deviation can also accumulate, that is to say there is regulation as long as the deviation is not zero. The greater the deviation, the greater the score and the larger the adjustment range [19]. The adjustment process is completed when the deviation is zero. In the actual adjustment process, it is also possible to slightly reduce the adjustment range in order to ensure the stability of the control. Thirdly, a proportional-integral derivative regulator exists to allow the control process to be completed in the shortest possible time. The deviation in the control process is analyzed. According to the predicted deviation situation, the control is adjusted, which can minimize the adjustment range and ensure the normal operation of the system [20].

Because of the control characteristics of the industrial system itself, deviation analysis should be performed according to the sampling conditions at the time when the system is running. Therefore, the circumscribed rectangular method is used for numerical integration, and the first-order backward difference is used for numerical differentiation [21]:

\[
u_i = K_p \left[ e_i + \frac{T}{T_I} \sum_{j=0}^i e_j + \frac{T_D}{T} (e_i - e_{i-1}) \right]. \tag{16}
\]

If the sampling period is small enough, this discrete approximation is quite accurate. In equation (16), \( u_i \) is the full output, which corresponds to the position that the actuator of the controlled object should reach at the sampling time of the \( i \)th time. Therefore, equation (16) is called a PID position type control equation, as shown in Figure 3.

It can be seen that when \( u_i \) is calculated as above, the output value is related to all the past states. When what the actuator needs is not the absolute value of the control quantity but its increment, the following equation can be derived:

\[
\Delta u_i = u_i - u_{i-1} = K_p \left[ e_i - e_{i-1} + \frac{T}{T_I} e_i + \frac{T_D}{T} (e_i - 2e_{i-1} + e_{i-2}) \right] \tag{17}
\]

or

\[
u_i = u_{i-1} + K_p \left[ e_i - e_{i-1} + \frac{T}{T_I} e_i + \frac{T_D}{T} (e_i - 2e_{i-1} + e_{i-2}) \right]. \tag{18}
\]

Equation (4) is called an incremental PID control equation. Equation (5) is called a recursive PID control equation. The quantitative control equation has the following advantages. First, the computer only outputs the control increment, that is, the change in the position of the actuator, so the influence of the malfunction is small. Second, the output \( u_i \) at time \( i \) only needs to use the deviation at this moment, the previous moment, the deviation \( e_{i-1} \) and \( e_{i-2} \) of the first two moments, and the previous output value \( u_{i-1} \), which greatly saves memory and calculation time [22]. Third, when the manual-automatic switching is performed, the control volume has a small impact and can be smoothly transitioned. The computer of the control process requires strong real-time performance. When the microcomputer is used as a digital algorithm, the necessary methods must be used to speed up the calculation due to the restrictions on word length and operation speed. The method of simplifying the equation is described below [23].

According to the recursive PID Equation represented by equation (5), each time the computer outputs \( u_i \), four additions, two subtractions, four multiplications, and two divisions are performed. The equation is slightly consolidated and written as follows:
Figure 3: PID algorithm. (a) PID algorithm linear adjustment process. (b) PID position control algorithm.
\begin{equation}
\begin{align*}
\frac{\partial}{\partial t} (\rho u_i u_j) + \frac{\partial}{\partial x_k} \left[ \rho u_i u_j u_k + \left( \rho + \rho \frac{\partial}{\partial x_k} \frac{\partial u_i}{\partial x_j} \right) u_k \right] &= - \frac{\partial}{\partial x_k} \left[ \rho \left( \frac{\partial u_i}{\partial x_k} + \frac{\partial u_k}{\partial x_i} \right) \nu \frac{\partial u_j}{\partial x_i} \right] + \frac{\partial}{\partial x_k} \left[ \rho \left( \frac{\partial u_i}{\partial x_k} + \frac{\partial u_k}{\partial x_i} \right) \nu \frac{\partial u_j}{\partial x_i} \right] \varepsilon_i - 2 \mu \frac{\partial u_i}{\partial x_k} \frac{\partial u_j}{\partial x_k} \\
&= - \rho \left( \frac{\partial u_i}{\partial x_k} \frac{\partial u_j}{\partial x_k} + \frac{\partial u_k}{\partial x_i} \frac{\partial u_i}{\partial x_j} \right) + \rho \left( \frac{\partial u_i}{\partial x_k} + \frac{\partial u_k}{\partial x_i} \right) \frac{\partial u_j}{\partial x_i} \nu \frac{\partial u_j}{\partial x_i} - 2 \mu \frac{\partial u_i}{\partial x_k} \frac{\partial u_j}{\partial x_k} + \frac{\partial u_i}{\partial x_k} \frac{\partial u_j}{\partial x_k} \varepsilon_i.
\end{align*}
\end{equation}

In equation (19), the coefficient \( a_0, a_1, \) and \( a_2 \) can be calculated discretely, thereby speeding up the operation of the algorithm program.

3. Results and Discussion

The RSM turbulence model and the PID algorithm are mainly used to simulate and study the dynamic model and numerical experiment of turbidity maximum zone in estuary. The specific contents of the numerical simulation study include the following aspects. Firstly, a multiresolution grid subdivision model for the largest turbid zone of the digital river inlet is constructed. Secondly, the PID algorithm is used to optimize the RSM turbulence model and for simulation calculation [24].

Before conducting the research, the digital modeling of river estuaries is required. According to the distribution and characteristics of the river bodies in the study area, one or more satellite remote-sensing data sources, such as GF-1, GF-2, Landsat TM/ETM+, HJ-1A, and HJ-1B, can be selected. The single-wavelength threshold method, the water body index method, the classification method based on prior knowledge or the object-oriented classification method are used to extract water, and the extracted water body is vectorized. The remote-sensing image data are used to effectively identify the river boundary line, as shown in Figure 4 [25].

Considering that the river channel is long and narrow, in the visualization process, the spatial position of the viewpoint changes, and only the local river area can be observed. The other areas are outside the computer window. If the river is modeled uniformly and the river is carefully observed during the process of roaming, the proportion of rivers outside the field of view is large [26]. If this part of the river is synchronized, it will inevitably affect the real-time interaction. Therefore, the river is first partitioned. If during the change of viewpoint, the river is not in the window, and it will be unloaded without rendering [27]. Partition can be conducted through the aspect ratio of the window. The multiresolution grid subdivision model of the largest turbid zone in the digital river inlet is shown in Figure 4.

After completing the digital modeling of the river estuary, the corresponding sensor equipment can be used to collect data on the most turbid zone of the river inlet. The AT89S52 chip is mainly used to make the corresponding data acquisition device placement, and all-weather data acquisition is conducted in the key position identified in Figure 4 [28]. AT89S52 is a small and has high performance and low power chip introduced by STC. The chips use the main features of flash memory technology, reducing the cost of production. Its software and hardware are fully compatible with the MCS-51-related manufacturing technology, making development and testing easier and providing intelligent flexibility and cheap solutions for many embedded control systems. The AT89S52 has the following features [29]. First, the AT89S52 and MCS-51 microcontrollers are fully compatible with the instruction set and pins. Second, an on-chip 4k byte line can reprogram Flash program memory. The working range of AT89S52 is 0 Hz~24 MHz. In addition, it also has the following characteristics: three-level program memory encryption, with 128×8-bit internal RAM with 32-bit bidirectional input and output lines. It has not only two 16-bit timers/counters but also five interrupt sources and two interrupt priorities and full duplex asynchronous serial ports [30].

After obtaining a large amount of data, it is necessary to use the corresponding mathematical model to excavate the contents of these data, thus obtaining the dynamic model of the formation of the largest turbid zone in the river mouth [31]. For river data mining, the most common in the industry is the use of RSM turbulence models for mathematical modeling. However, this model not only is computationally complex but also lacks accuracy in the calculation of low Reynolds pressures. Therefore, the PID algorithm is used to optimize the RSM turbulence model to obtain a simpler and more accurate turbulence model. The optimization process is as follows.

The equation for the RSM turbulence model is shown below:
In equation (20), the variables $D_{T_{ij}}, G_{ij}, \varphi_{ij}$, and $\epsilon_{ij}$ need to establish a corresponding mode for closing operation, and the variables $G_{ij}, D_{L_{ij}}, F_{ij}$, and $F_{ij}$ do not need sealing treatment.

For this model, the PID equation can be used to optimize the derivative. It is supposed that there is a quadratic polynomial as follows:

$$p_2(x) = a_0 + a_1x^1 + a_2x^2.$$  \hspace{1cm} (21)

The difference $f$ is at points $x_0, x_1,$ and $x_2$, that is, the local coordinate system is used to make $x_i = 0, x_{i+1} = h,$ and $x_{i+2} = 2h$; then,

$$f(x_i) = a_0 + a_1x_i + a_2x_i^2 = a_0,$$

$$f(x_{i+1}) = a_0 + a_1x_{i+1} + a_2x_{i+1}^2 = a_0 + a_1h + a_2h^2,$$

$$f(x_{i+2}) = a_0 + a_1x_{i+2} + a_2x_{i+2}^2 = a_0 + a_1(2h) + a_2(2h)^2.$$  \hspace{1cm} (22)

These three equations with three unknowns can be converted into

$$a_0 = f(x_i) = f(0),$$

$$a_1 = \frac{-f(x_{i+2}) + 4f(x_{i+1}) - 3f(x_i)}{2h} = \frac{-f(2h) + 4f(h) - 3f(0)}{2h},$$

$$a_2 = \frac{f(x_{i+2}) - 2f(x_{i+1}) + f(x_i)}{2h^2} = \frac{f(2h) - 2f(h) + f(0)}{2h^2},$$

where $a_i, i = 1, 2, 3,$ are obtained, and equation (1) is derived:

$$f'(x) = a_1 + 2a_2x.$$  \hspace{1cm} (24)

Then, the expression is calculated in A; then, we obtain

$$f'(x) = \frac{-f(x_{i+2}) + 4f(x_{i+1}) - 3f(x_i)}{2h}. $$  \hspace{1cm} (25)

Regarding the point $x$, $f$ is smooth enough; then, the Taylor series expansion of $f$ can be expressed as

$$f(x + h) = f(x) + h \frac{df}{dx}(x) + \frac{h^2}{2!} \frac{d^2f}{dx^2}(x) + \frac{h^3}{3!} \frac{d^3f}{dx^3}(x) + \cdots.$$  \hspace{1cm} (26)

The function $f(x)$ on the right side of (10) is moved to the left side of (10); then, it is divided by $h$ to get the standard deviation quotient:

$$f(x + h) - f(x) = \frac{d f(x)}{dx} + \left\{ \frac{h^2}{2!} \frac{d^2 f(x)}{dx^2} + \frac{h^3}{3!} \frac{d^3 f(x)}{dx^3} + \cdots \right\}.$$  \hspace{1cm} (27)

Let $h \to 0$; the items in braces disappear. Defined by derivative, then

$$f'(x) = \lim_{h \to 0} \frac{f(x + h) - f(x)}{h}.$$  \hspace{1cm} (28)

At this time, the difference quotient $(f(x + h) - f(x))/h$ is used to replace $f'(x)$, resulting in an error:

$$f'(x) - \frac{f(x + h) - f(x)}{h} = \left\{ \frac{h^2}{2!} \frac{d^2 f(x)}{dx^2} + \frac{h^3}{3!} \frac{d^3 f(x)}{dx^3} + \cdots \right\}.$$  \hspace{1cm} (29)

A linear operator from equation (29) is extracted:

$$T(f) = \left( \frac{h}{2!} \frac{d^2}{dx^2} + \frac{h^2}{3!} \frac{d^3}{dx^3} + \cdots \right) f(x).$$  \hspace{1cm} (30)

At the same time, according to different representatives, the error between the corresponding differential operator $Df = df/dx$ and the approximate linear operator $D_h f = (f(x + h) - f(x))/h$ is constructed. The truncation error obtained here represents the error in the linear operator $L$.  

**Figure 4:** Digital estuary. (a) Remote-sensing image of river boundary. (b) Multiresolution mesh subdivision model for maximum turbidity zone. (c) Dynamic model simulation results of the maximum turbidity zone formed in the estuary of the river.
Let $L_h$ be a discrete approximation on the neighborhood of the maximum $h$ defined by the linear differential operator $L$. If there are constants $C > 0$, $p > 0$, and $h_0 > 0$, then

$$T(\varphi) = \| (L - L_h) \varphi \| \leq C h^p, \forall \varphi \in C^p, \forall h < h_0.$$  \hspace{1cm} (31)

Then, $L_h$ has a truncation error of $O(h^p)$.

In equation (32), the limit value for any smooth $f$ and sufficiently small $h$ is calculated:

$$\lim_{h \to 0} T(f) = h \left| \frac{f''(x)}{2} \right|.$$  \hspace{1cm} (32)

Formally, because of this, when the variable approaches infinity to zero, the truncation error can be defined by the convergence given by the method given in (31). Formally because of this, truncated error is $T(f)$. When the variable $h$ approaches infinity to zero, the convergence of $O(h)$ can be defined by the method given in (31).

When $h|f^{(4)}|/6 + \cdots$ is much smaller than $h|f|^n/2$, $f$ is calculated to find its approximate value. If the second derivative of function $f$ is much less than the other derivative within the effective range, then

$$0 < |f^n(x)| \leq \left| f^{(0)}(x) \right|, \quad n > 2.$$  \hspace{1cm} (33)

The Taylor series of function $B$ is solved at point $A$:

$$f(x + h) = f(x) + h f'(x) + \frac{h^2}{2!} f''(x) + \frac{h^3}{3!} f'''(x) + \frac{h^4}{4!} f^{(4)}(x) + \cdots.$$  \hspace{1cm} (34)

The simulation equation for the dynamic model formed by the largest turbid zone in the river inlet is obtained:

$$\frac{Dk}{Dt} = P_k + \frac{\partial}{\partial x_j} \left( \frac{v + \sigma_k}{\sigma_j} \frac{\partial k}{\partial x_j} \right),$$

$$\frac{De}{Dt} = \frac{C_{1e} P_k - C_{2e} e}{T} + \frac{\partial}{\partial x_j} \left( \frac{v + \sigma_e}{\sigma_j} \frac{\partial e}{\partial x_j} \right),$$

$$\frac{Dn^2}{Dt} = k f - 6 v^2 e_k + \frac{\partial}{\partial x_j} \left( \frac{v + \sigma_n}{\sigma_j} \frac{\partial n^2}{\partial x_j} \right),$$

$$L^2 \nabla^2 f - f = \frac{(C_{1e} - 1)}{T} + \left[ \frac{v^2}{k} \frac{2}{3} \right] - \frac{C_{1e} P_k}{k} - 5 \frac{v^2}{T k}.$$  \hspace{1cm} (35)

At this time, the data information acquired by the sensing device is substituted into the simulation equation of the power mode to calculate, and the results can be obtained.

In this paper, through numerical simulation and theoretical analysis, the dynamic flow formed by the solid-liquid turbid zone in the estuary is simulated and calculated, and the best operating parameters are obtained through industrial test, and the automatic control of numerical prediction is realized. The specific conclusions are as follows.

The RSM turbulence model and PID algorithm are used to calculate the dynamic model and numerical simulation of the formation of turbidity maximum zone in the estuary, and the turbulent flow is studied. The results show that only the Reynolds stress model can give the correct tangential, axial, and radial velocity distribution. The RSM model can also give the results close to the actual results in a certain range, but the numerical prediction results for the radial and conical sections of the dynamic model are not reasonable. In order to describe the turbulent internal flow accurately, the Reynolds stress model must be used.

4. Conclusions

Due to the influence of marine civilization, estuarine and coastal areas have become one of the most densely populated areas in the world. More than half of the world’s population live in estuaries and coastlines. Due to the influence of human activities and the natural movement of the river itself, a very complex water environment is produced at the estuary. The rich diversity of sediments and the changes of water flow bring great challenges to the management of estuaries. The RSM turbulence model and PID algorithm are used to study the dynamic model and numerical simulation of the formation of the turbidity maximum zone in the estuary. The research work of these two aspects has been completed. Firstly, the multiresolution mesh subdivision model of turbidity maximum zone in digital estuary is established. Secondly, the PID algorithm is used to optimize the RSM turbulence model, and the simulation results are good. Based on the RSM turbulence model and PID algorithm, a multiresolution mesh subdivision model for turbidity maximum area of digital estuary is studied. It has its unique advantages. In order to overcome the shortcomings of static hydraulic control, it is necessary to improve the real-time control. The real-time performance of turbulence simulation control system is related to the accuracy of output and the synchronization of multichannel, which determines the performance of the system to a certain extent. At present, there are still some problems in the synchronization of the model, which leads to the instability of the start-up and stop of the system. In order to solve this problem, on the one hand, we need to improve the real-time performance of the system and, on the other hand, we need to develop new software algorithms to solve this problem.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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