CALCULATION OF THE EFFICIENCY OF THE HORISONTAL SETTLER WITH BAFFLES

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РАСЧЕТ ЭФФЕКТИВНОСТИ РАБОТЫ ГОРИЗОНТАЛЬНОГО ОТСТОЙНИКА С ПЛАСТИНАМИ

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The main purpose of this paper is development of the effective CFD model which can be used for computation speed field of the flow in the horizontal settlers which takes into account the geometrical form of the settler.

Introduction. Horizontal settler is one of the most important part in the water treatment system. Nowadays often the horizontal settlers with comprehensive geometrical form are proposed by designers. According to this the real lack of methods to calculate the efficiency of these settlers is an obvious problem.

Literature review. To calculate the efficiency of horizontal settlers the empirical models are widely used in Ukraine and abroad. These models do not take into account the geometrical form of the horizontal settlers and the peculiarities of the sedimentation process [3, 5, 6]. Therefore, it is important to develop CFD models having more capabilities to simulate the process of the waste waters treatment in settlers and which do not need much computational time for running and allow to take into account the geometrical form of settlers [1, 2].

The objective. The main objective of this paper is the development of the effective computer model which is more effective than the employed in Ukraine models and which can be used for prediction of the horizontal settler efficiency.

Modeling equations. To simulate the process of the water purification in the horizontal settler the transport equation (1) is used [1, 2]:

$$\frac{\partial C}{\partial t}+\frac{\partial uC}{\partial x}+\frac{\partial (v-w)C}{\partial y}+\sigma C=\frac{\partial}{\partial x}\left(\mu_x\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu_y\frac{\partial C}{\partial y}\right), \quad (1)$$

where C is the concentration; u, v are the velocity components in x, y direction respectively;

w – is the speed of the gravity fallout;

σ is the parameter taking into account the process of flocculation and decay;

μ_x, μ_y are the coefficients of turbulent diffusion in x, y direction respectively;

x_i, y_i are the Cartesian coordinates;

The transport equation is used with the following boundary conditions [1, 2, 4]:

– inlet boundary: $C|_{inlet}=C_E$, where C_E is the known concentration (in the case study of this paper it is dimensionless and equal to $C_E=100$);

– outlet boundary: in numerical model the condition $C(i+1,j)=C(i,j)$ is used. Here, C(i+1,j) is the concentration at the outlet boundary (this boundary condition means that we neglect the process of diffusion at this plane).

Fluid Dynamic Model. To simulate the flow in the horizontal settler the model of the invisid fluid is used. In this case the governing equations are

1) Poisson equation for flow function:

$$\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}=-\omega. \qquad (2)$$

2) Equation of the vorticity transfer :

$$\frac{\partial\omega}{\partial t}+\frac{\partial u\omega}{\partial x}+\frac{\partial v\omega}{\partial y}=0 \qquad (3)$$

where $\omega=\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}$ is vorticity.

The initial and boundary conditions for these equations are discussed in [8].

Numerical integration. To solve the mass conservation equation (1) the implicit difference scheme of splitting is used [8]. Numerical integration is carried out using rectangular grid. To form the computational region and the form of the baffle markers are used in the numerical model[8].

To solve equation of the vorticity transfer (3) the following difference scheme is used [8]:

- at the first step of splitting

$$\frac{\omega_{i,j}^{n+\frac{1}{2}}+\omega_{i,j}^{n}}{\Delta t}+\frac{u_{i+1,j}^{+}\omega_{i,j}^{n+\frac{1}{2}}-u_{i,j}^{+}\omega_{i-1,j}^{n+\frac{1}{2}}}{\Delta x}+\frac{v_{i,j+1}^{+}\omega_{i,j}-v_{i,j-1}^{+}\omega_{i,j-1}}{\Delta y}=0;$$

- at the second step of splitting

$$\frac{\omega_{i,j}^{n+1}-\omega_{i,j}^{n+1}}{\Delta t}+\frac{u_{i+1,j}^{-}\omega_{i+1,j}^{n+1}-u_{i,j}^{-}\omega_{i,j}^{n+1}}{\Delta x}+\frac{v_{i,j+1}^{-}\omega_{i,j+1}^{n+1}-v_{i,j-1}^{-}\omega_{ij}^{n+1}}{\Delta y}=0.$$

The unknown meaning of vorticity is obtained from these expressions using the explicit formulae of “running calculation”.

To solve Poisson equation (2) the following difference scheme of splitting is used:

- at the first step of splitting

$$\frac{\psi_{ij}^{n+\frac{1}{4}}-\psi_{ij}^{n}}{\Delta t}=\frac{\overline{\psi_{ij}}}{2};$$

- at the second step of splitting

$$\frac{\psi_{i,j}^{n+\frac{1}{2}} - \psi_{i,j}^{n}}{\Delta t} = -\frac{\psi_{i,j}^{n+\frac{1}{2}} - \psi_{i-1,j}^{n+\frac{1}{2}}}{\Delta x^2} - \frac{\psi_{i,j}^{n+\frac{1}{2}} - \psi_{i,j-1}^{n+\frac{1}{2}}}{\Delta y^2};$$

- at the third step of splitting

$$\frac{\psi_{i,j}^{n+\frac{3}{4}} - \psi_{i,j}^{n+\frac{1}{2}}}{\Delta t} = \frac{\psi_{i+1,j}^{n+\frac{3}{4}} - \psi_{i,j}^{n+\frac{3}{4}}}{\Delta x^2} + \frac{\psi_{i,j+1}^{n+\frac{3}{4}} - \psi_{i,j}^{n+\frac{3}{4}}}{\Delta y^2};$$

- at the last step

$$\frac{\psi_{ij}^{n+1} - \psi_{ij}^{n+\frac{3}{4}}}{\Delta t} = \frac{\overline{\omega_{ij}}}{2},$$

where $\overline{\omega_{i,j}} = \frac{1}{4}\left(\omega_{i,j} + \omega_{i-1,j+1}\omega_{i-1,j-1} + \omega_{i,j-1}\right).$

On the basis of the developed numerical model code was created using FORTRAN language.

Results. The developed computer model was used to compute water purification in the horizontal settler with baffles (Fig.1). Dimensions of the computational region are 12 m*4,3 m; flow speed at the inlet plane is 5 m/h; diffusion coefficient is 0,9 m^2/h; fallout speed is 0,08 m/h. In Fig. 2 the concentration field in the settler is presented.

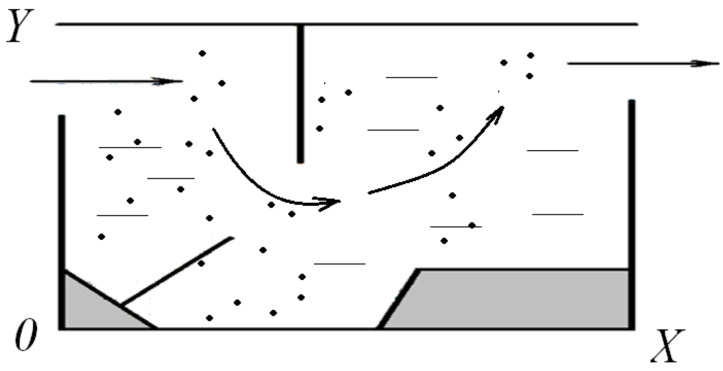

Fig. 1. Sketch of the horizontal settler with baffles.

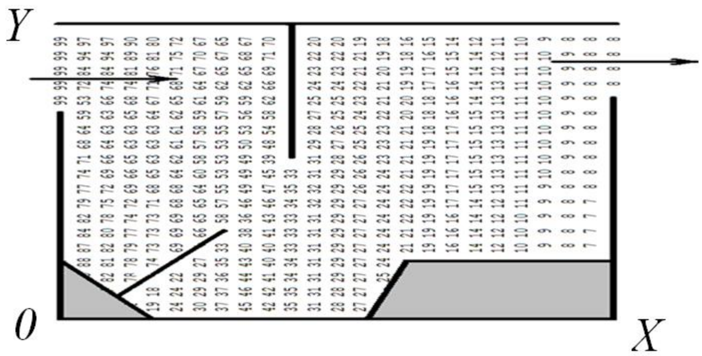

Fig. 2. Concentration field in the settler

As we see from this figure, the concentration at the exit plane is 8% from the initial concentration at the inlet plane. The concentration under the baffle is about 33 %. As we see from Fig. 2, the intensive fallout takes place in the region before the baffle.

The computational time to solve the problem was about 10 *sec*. So the developed computational model can be used to predict very quickly the concentration field in the settler having comprehensive geometrical form. In future the 3-D CFD model is proposed to be developed.

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