Artificial Upwelling Simulation in Closed Environment

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Abstract: Artificial upwelling technology has great significance in improving the marine environment, increasing fishery resources, enhancing the safety of marine transportation and improving the ecological environment of rivers and lakes. According to the characteristics of temperature differential liquid hoisting system in closed environment, we built the computer simulation of differential thermal upward flow in this paper. By setting the initial water temperature, heating power of heat source and the diameter of closed pipe, analyzed the influence of these factors on the characteristics of upwelling velocity field and temperature field. The experimental results show that the higher the heat source power is, the higher the artificial upwelling velocity is and also the higher rising flow rate will be.

1. Introduction

China has a vast ocean line and rich marine resources. Fishing grounds alone occupy 1.5 million square kilometers. The huge fishing grounds bring considerable economic benefits to the coastal areas and promote the economic development of the coastal areas.

Nowadays, people pay more and more attention to the exploitation of marine resources, which contains a lot of renewable energy such as tidal energy, so it is very important for the rational exploitation and utilization of marine resources.

The differential thermal artificial upwelling technique is used to artificially heat the seawater in the deep low temperature water layer, forming a local thermal temperature zone in the low temperature water layer. According to the principle of fluid mechanics, the temperature gradient in the flow body will cause the density gradient. Usually the high temperature fluid density is lower and the low temperature fluid density is higher .So the low density seawater in the hot temperature region will rise naturally under the action of the buoyancy caused by gravity and produce upwelling. In this paper, by means of numerical simulation, the differential thermal human in pipe has been studied. A series of fundamental studies have been carried out on the characteristics of velocity field and temperature field of upward flow.

This paper focuses on the study of the differential thermal upwelling in the pipe. In the closed environment, the heat propagation of the water and the diffusion and mixing of the upwelling in the flow process are directly restricted by the pipe wall. At this point, the driving force and the flow rate of the temperature difference liquid lift are directly related not only to the heat source parameters and the series of water parameters, but also to the parameters of the tube (including the geometric parameters and the physical parameters of the pipe wall). Therefore, the study of artificial upwelling in closed environment should begin with water temperature, heating power and pipeline physical parameters.

2. Mesh division and parameter design

2.1 Introduction of CFD

CFD solves the fluid dynamics control equation by numerical calculation, and obtains the results by computer numerical calculation, including the numerical value of flow field parameter at discrete

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point. CFD, theoretical analysis and experimental study, make up a complete system of hydrodynamics. Each of them has its own advantages and disadvantages. CFD can supplement and explain the theoretical analysis and experimental research, and has an advantage that is not restricted by realistic conditions and has good adaptability. The basic equations include the mass conservation equation, momentum conservation equation and energy conservation equation. CFD studies the problems of fluid mechanics on the basis of these three governing equations.

B.CFD basic control equation

(1) Continuity Equation

Any movement of liquids follows the conservation laws of energy and matter in physics. The conservation equation of mass is derived from the law of conservation of mass in physics, which is also called continuity equation.

$$\frac{\partial}{\partial t}\iiint_{Vol} \rho \, dx \, dy \, dz + \oint\!\!\oint_{A} \rho dA = 0$$

When calculated in a rectangular coordinate system, the above equation can be expressed in the following differential form:

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho v)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$$

(2) Momentum Equation

The study of fluid flow involves the study of motion, so the momentum equation of fluid flow can be derived according to Newton's second law. The mathematical expression of the equation is as follows:

$$\delta_F = \delta_m \frac{dv}{dt}$$

The N-S equation can be derived when it is in a rectangular coordinate system:

$$\begin{cases} p\frac{du}{dt} = pF_x - \frac{\partial p}{\partial x} + \frac{\partial}{\partial x}(\mu\frac{\partial u}{\partial x}) + \frac{\partial}{\partial y}(\mu\frac{\partial u}{\partial y}) + \frac{\partial}{\partial z}(\mu\frac{\partial u}{\partial z}) \\ \quad + \frac{\partial}{\partial x}\left[\frac{\mu}{3}(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z})\right] \\ p\frac{dv}{dt} = pF_y - \frac{\partial p}{\partial y} + \frac{\partial}{\partial x}(\mu\frac{\partial v}{\partial x}) + \frac{\partial}{\partial y}(\mu\frac{\partial v}{\partial y}) + \frac{\partial}{\partial z}(\mu\frac{\partial v}{\partial z}) \\ \quad + \frac{\partial}{\partial y}\left[\frac{\mu}{3}(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z})\right] \\ p\frac{dw}{dt} = pF_z - \frac{\partial p}{\partial z} + \frac{\partial}{\partial x}(\mu\frac{\partial w}{\partial x}) + \frac{\partial}{\partial y}(\mu\frac{\partial w}{\partial y}) + \frac{\partial}{\partial z}(\mu\frac{\partial w}{\partial z}) \\ \quad + \frac{\partial}{\partial z}\left[\frac{\mu}{3}(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z})\right] \end{cases}$$

2.2 Grid division

The geometric model of closed artificial upwelling numerical simulation is set as 700x400x550, the length of closed pipe is set to 425, and the diameter is 40. Because the simulation area is simple, the structural grid is used to mesh the geometric model, which can not only guarantee the quality of the grid, but also save computer resources. In this paper, the grid generation software ICEM14.5 is used to mesh the differential thermal upwelling flow field.

In order to obtain higher quality mesh, O type mesh is used near the region where the heat source is located, as shown in Fig 1. Considering that the main area of effect of the upwelling driven by temperature difference near the heat source is concentrated near the heat source and along the vertical axis of the heat source, and that the velocity of velocity and the temperature change in this region are relatively large, which is the main area of upwelling and is also the key area of our research, So the grid in this area is relatively dense and gradually increasing outward. In addition, the velocity gradient of the water tank wall is large, so the grid at the wall surface is also encrypted, and the overall grid is set up as shown in Fig 2.

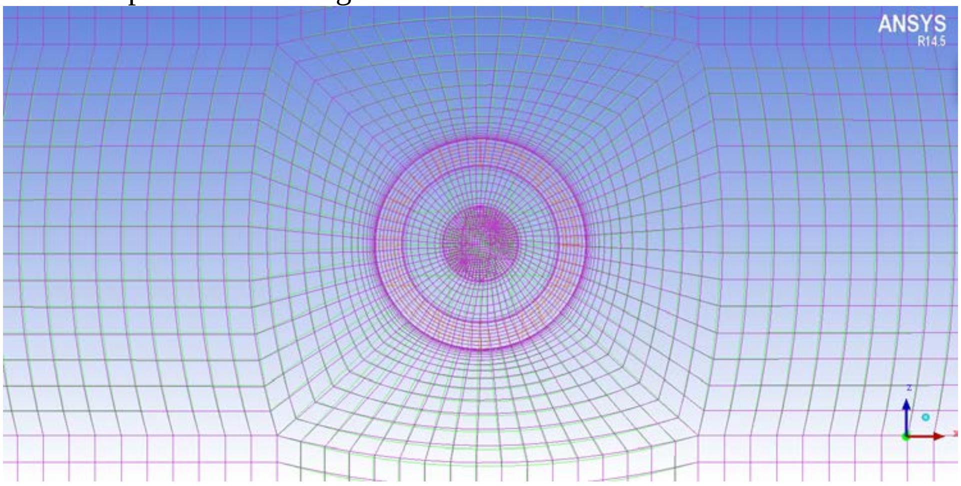

Figure 1. Central and wall meshes of heat sources

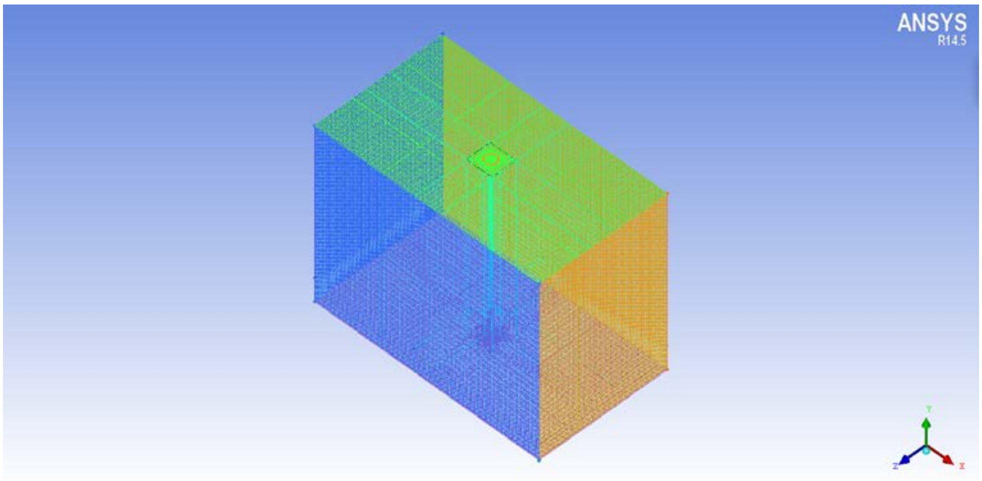

Figure 2. Overall grid setup

2.3 Parameter setting&Calculation model selection

The differential heat type artificial upwelling technology is to heat the fluid through a heat source, so that the temperature of the fluid rises and the density decreases, and the fluid will rise naturally under the action of the buoyancy caused by gravity. This upwelling is a natural convection.

The Realizable k-ε model is suitable for the flow in the pipeline, so the Realizable k-ε model is used for the numerical simulation of upwelling flow in this paper. Because the upper part of the differential heat artificial upwelling flow field is in contact with the air, there is a layer of gas-liquid interface. In order to simulate the real environment more accurately and ensure the calculation accuracy, the VOF two-phase flow model is used in the upper part of the model.

Fluent parameter settings:

Material setup: this simulation involves two-phase flow, the gas phase selected from the Fluent Database air air, as shown in Fig 3, the liquid phase needs to set its own parameters.

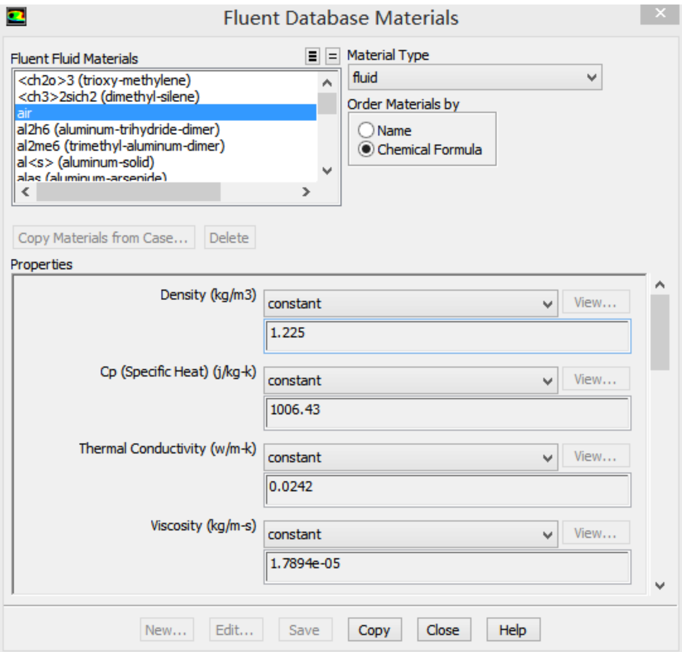

Figure 3. Material setting

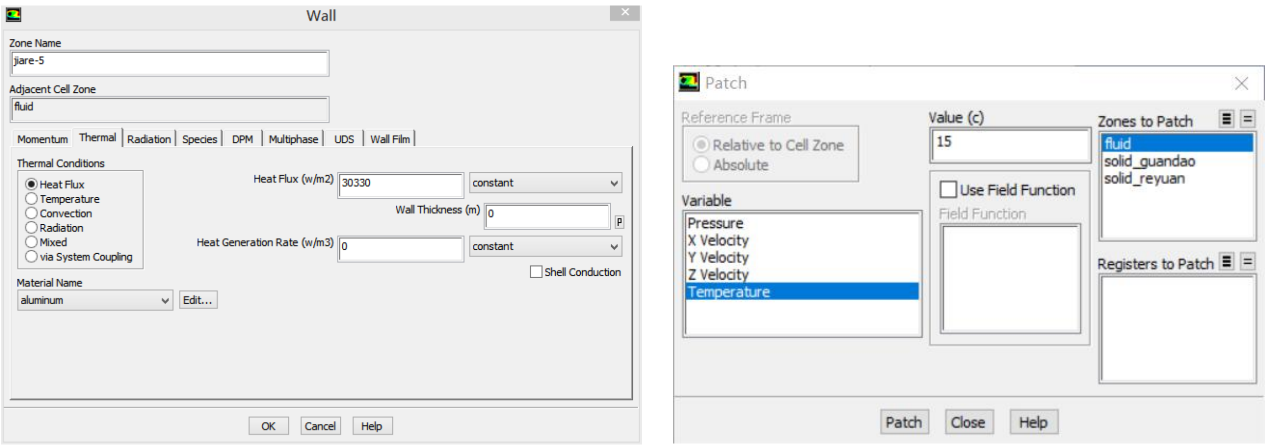

Figure 4. Heating power and initial temperature setting

3. Simulation result analysis

The flow field, such as velocity cloud image, vector graph and so on, can be observed by post processing software Fieldview. As shown in the following figures, partial flow Field Diagram of simulated differential Thermal upward flow in closed Environment. It can be seen from the figures that there is a higher upward flow in the vertical tube. There is a symmetrical return region near the entrance of the lower end of the vertical tube and the exit of the upper end of the vertical tube. Constrained by the vertical tube wall, the upwelling flow beam is mainly concentrated in the space of the vertical tube.Upwelling vertical cross section velocity cloud map and vertical cross section velocity vector diagram, as shown in the following figure.

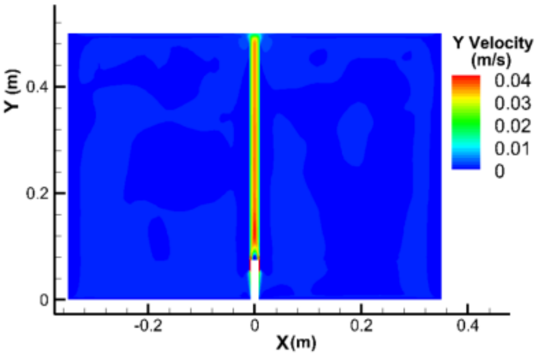

Figure 5 a. Vertical Cross Section Velocity Cloud Picture of differential Thermal upward flow in closed Environment

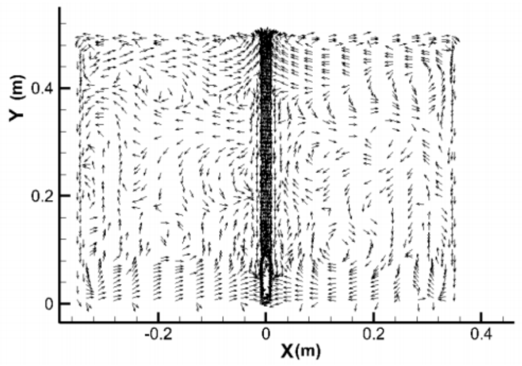

Figure 5 b. Vertical Cross Section Velocity Vector Diagram of differential Thermal upward flow in closed Environment

According to the simulation results, when the initial water temperature is 15℃ and the heating power is 200w, the rising characteristic velocity changes with the height as shown in the Fig.6:

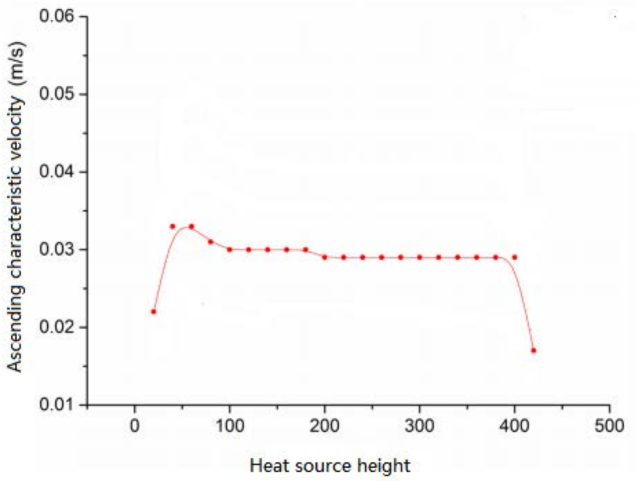

Figure 6. Curve of rising characteristic velocity with height

From the above figure, it can be seen that under certain heating power, the rising characteristic velocity of fluid in the tube rises rapidly from 0-50, then keeps steady, and decreases sharply at 400-425.

4. Conclusion

In this paper, the basic characteristics of the differential thermal upwelling field in closed environment are studied systematically by numerical simulation. The mathematical model of differential thermal artificial upwelling is established. The numerical simulation of differential thermal artificial upwelling is carried out by using Fluent14.5, and the influence of a fixed parameter on the characteristic parameters of upwelling is also discussed. Using the same mathematical model to simulate the differential thermal artificial upwelling in closed environment, the basic characteristics of the upwelling in closed environment are investigated, and the influence of different parameters on the vertical pipe liquid lifting process is analyzed. In this paper, the differential thermal artificial upwelling flow field in closed environment is preliminarily explored, and the influence of different parameters on the upwelling flow should be considered in the future. In addition, the influence of pipeline material is not taken into account in numerical simulation, and the flow characteristics of upwelling in closed environment still need to be studied in detail.

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