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Original Research Paper

Research on the Return Water Flow Velocity of a Water Source Heat Pump System

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ABSTRACT

The water temperature field of the lake water source heat pump air-conditioner system in Guilin Ronghu is simulated in this paper basing on the numerical simulation software of CFD. The effects of the return water velocity are discussed. The paper comes to the conclusions that the effect of the return water's velocity on the influenced lake water area and the temperature field is great, and using the suitable return water's velocity can reduce the disadvantageous to ecological environment.

INTRODUCTION

Guilins scenery is the best in the world, the two rivers and four lakes that are located in the central city, are the most beautiful scenery. The four lakes are Mulonghu, Guihu, Ronghu and Shanhu, the total water volum is about 69 million cubic meters, the depth of the water is about 2 metres, and the lake water is replaced every 4-10 days (Baidu Baike 2013). The four lakes are shown in Fig. 1 (Baidu map 2013).

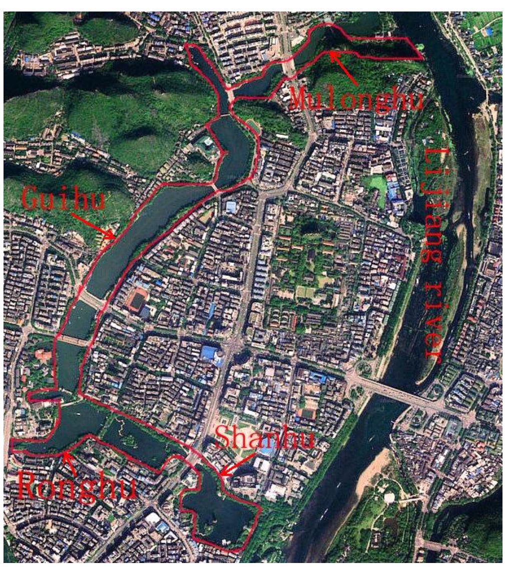


Fig. 1: The four lakes in Guilin.

As energy-saving and low carbon type air conditioning system, water source heat pump air-conditioner system is worthy of popularization and application in Guilin (Qi Tang 2010), where the surface water is rich. CFD numerical simulation of the water source heat pump system can provide reference for the building of the system to reduce the disadvantage to ecological environment.

MATHEMATICAL MODEL

The steady flow mathematical model is built, and the water through the heat pump system meet the control equations as follows (water density is constant):

Continuous equation:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \qquad ...(1)$$

Momentum equations (Navier-Stokes equations):

$$r\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=m\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)+S_u-\frac{\partial p}{\partial x} \qquad ...(2)$$

$$r\left(u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}\right)=m\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)+S_v-\frac{\partial p}{\partial y} \qquad ...(3)$$

$$r\left(u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)=m\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)+S_w-\frac{\partial p}{\partial z} \qquad ...(4)$$

Energy equation:

$$a\left(\frac{\partial^2 t}{\partial x^2}+\frac{\partial^2 t}{\partial y^2}+\frac{\partial^2 t}{\partial z^2}\right)=u\frac{\partial t}{\partial x}+v\frac{\partial t}{\partial y}+w\frac{\partial t}{\partial z} \qquad ...(5)$$

For the water flow is turbulent, turbulence model k-ε equation is used.

NUMERICAL SIMULATION

Modelling and its basis: The water temperature of the lake water source heat pump air-conditioner system in Guilin Ronghu is simulated. Lijiang river flow through the Mulonghu and Guihu to Ronghu, and then flow out of it to Shanhu or Taohua river. The distance from the east to the west of Ronghu is 860m, and the distance from the north to the south is 110m, the surface area is about 9.46 hectares. The shape saw from the satellite map looks like 'λ'. The shape is measured and simplified the shape, that is, take the half of the shape. The length from the intake of the heat pump system and the outlet of the lake is 220m, the intake is located in the upper reaches of the lake, the depth of the river is 2m, and the distance of the intake channel and the return channel is 50m. Without considering the influence of the bridge on water and the island, do not consider the heat lose of the return water pipe, the model is build and shown in Fig. 2.

Simulation data: The most unfavourable operation condition of the system in summer was simulated.

The volume flow rate of Ronghu in summer is chosen as 1.6 m^3/s (entirely renew the water every 5 days).

By comparing the historical data of the air temperature, the highest temperature of 33°C was chosen as the lake water's temperature. The return water's temperature of the heat pump system is 38°C, thus the temperature difference is 5°C.

The source water volume flow rate of the heat pump system is chosen as 0.167m^3/s. The water is drawn into the heat pump unit by water pump from the lake's upstream. The size of the intake channel is 1×1m^2, and the velocity of the intake source water is about 0.167m/s. The low velocity is in favour of preventing the sand into the unit's heat exchanger, and protecting the fish or shrimp from the rapid stream.

The effects of the return water on the temperature field

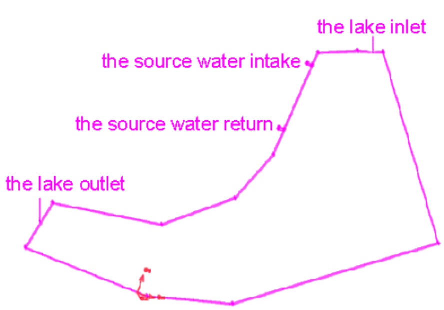
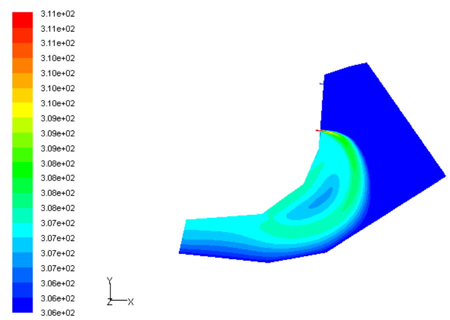
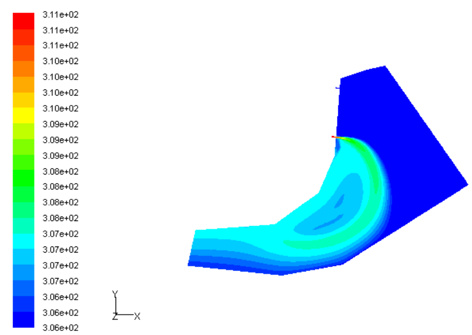


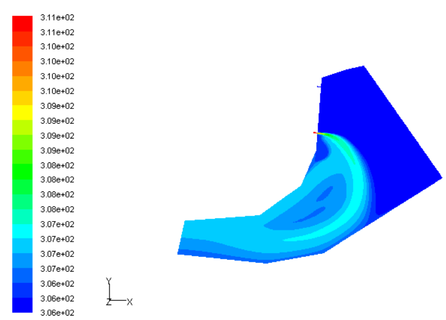
Fig. 2: Simplified model of Ronghu.



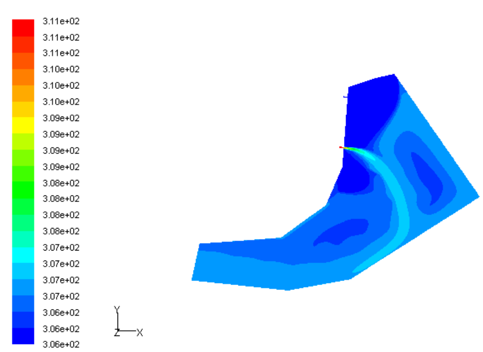
(a) The return channel size is 1.5×1m^2



(b) The return channel size is 1.5×0.8m^2



(c) The return channel size is 1.5×0.6m^2



(d) The return channel size is 1.5×0.4m^2

Fig. 3: Contours of static temperature at a depth of 0.2 metres.

Table 1: Lake water average temperature at a depth of 0.2 metres.

No.	Return channel size (m^2)	Average temperature at a depth of 0.2 metres (K)
1	1.5×1	306.7792
2	1.5×0.8	306.7524
3	1.5×0.6	306.7171
4	1.5×0.4	306.7408

of the lake water are simulated based on the numerical simulation software of CFD. The sizes of the return channel are $1.5×1m^2$, $1.5×0.8m^2$, $1.5×0.6m^2$ and $1.5×0.4m^2$ respectively. The flow direction of the intake and the return are both vertical to the lakeside. The convective heat transfer coefficient between the air and the lake water is $8W/(m^2.K)$.

Simulation results: The contours of static temperature at a depth of 0.2 meters are shown in Fig. 3, which use the return channel size with $1.5×1m^2$, $1.5×0.8m^2$, $1.5×0.6m^2$ and $1.5×0.4m^2$ respectively, thus the velocity of the return water is 0.1113m/s, 0.1392m/s, 0.1856m/s and 0.2783m/s respectively.

The lake water average temperatures at a depth of 0.2metres are shown in Table 1 when the return channel size are $1.5×1m^2$, $1.5×0.8m^2$, $1.5×0.6m^2$ and $1.5×0.4m^2$ respectively.

The change regulation of the lake water's temperature field with the various velocities of the return water is observed. The effects of the various return water flow rate are discussed. The contours show that the effect of the return water flow rate or the size of the return channel on the lake water's temperature field is obvious. The main points are as follows:

1. The higher the return water's velocity, the greater the area of lake water influenced, the more concentrative the relative high temperature area, that is, the jet-flow's average static temperature of the return water is relatively high.
2. The lower the return water's velocity the larger the flow sectional area of the return channel, the more uniform the lake water's temperature. But because of the influence of the lake shape, the return water will obviously backflow when flow down along the lake as shown in Fig. 3(a). As the area of the dark green is large, the heat transfer to air is restricted.
3. If the velocity of the return water is large, the return water will backflow to the upstream of the lake as shown in Fig. 3(d). The backflow can make short circuit of water temperature, and do harm to the heat pump system operation.
4. Both Fig. 3 and Table 1 indicate that the relative ideal contour is Fig. 3(c), for its return water has not short circuit of temperature, its average static temperature is relative low, and its high temperature area is not so large.

CONCLUSION

To sum up, the effect of the return water's velocity on the influenced lake water area and the temperature field is great. Using the suitable return water's velocity, we can reduce the disadvantages to ecological environment limitedly.

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