
Lang Luo, Yue-Jin Yu, Li-Peng Zheng and Wen Xia

ABSTRACT: Vertical single U-shaped ground tube is presented in this paper based on the research of the three-dimensional heat transfer model, using the numerical simulation method to study Nanjing area in summer conditions ground heat exchanger. Under the condition of not adding insulation board, comparing the influence of different inlet velocity on the heat exchanger, and then compared the adding different length of insulation surface heat exchanger heat transfer capacity, the influence of the comparative analysis of the results show that the inlet velocity under different operating conditions and the influence on the buried pipe outlet temperature and heat transfer, adding heat shield does not necessarily slow down the hot short circuit, so the heat exchanger, heat transfer performance and fuel economy must be considered to choose the best length of insulation board.

KEYWORD: Vertical U-shaped ground tube; Numerical simulation; Insulation board; Thermal short circuits

1 INTRODUCTION
Ground source heat pump system is circulating fluid through pipes and soil to heat exchange, so as to realize the air conditioning cooling or heating. In developed cities of our country, because land is nervous, vertical buried tube is more suitable for our country people, the actual situation of water resources shortage, which has been widely applied at present. Compared with traditional air conditioning system, the ground source heat pump system to the earth as a heat source and heat sink which uses the renewable energy, has the good characteristics of energy saving and environmental protection.

Research of heat transfer performance of ground heat exchanger is the emphasis and difficulty in buried pipe system, the phenomenon of hot short circuit of tube exchanger directly affects the heat transfer performance of heat exchanger, influence the working efficiency of the ground source heat pump system. So the study of the buried pipe hot short circuit phenomenon for better promotion and application of ground source heat pump has positive significance.

2 BURIED PIPE THERMAL SHORT-CIRCUIT PHENOMENON
Due to the restrictions on the size of drill (about 110 ~ 180 mm), two U-shaped tube
branch pipe spacing is small, and there is temperature difference between the two tubes filled with larger thermal conductivity of backfill material, make the two branch pipe must be heat reflux, and hot short circuit phenomenon. Hot short circuit phenomenon occurs between the two branch under heating conditions, the water temperature is lower than the ideal outlet temperature (simulated two tube far enough without hot short-circuit), namely lower import and export temperature difference. Under the working condition of refrigeration, the water temperature is higher than the ideal temperature, import and export temperature difference decreases. Hot short-circuit occurs between branches, inevitably produce certain effect to the actual heat transfer effect.

This article adopts the method of three-dimensional numerical simulation study and analysis of hot short circuit, and adding different depth between the two branch pipes insulation board, which explores to add insulation board and the influence of different depth of insulation surface hot short circuit, and then explores the insulation surface heat exchanger heat transfer of the star can influence.

3 NUMERICAL SIMULATION

3.1 Simulation assumptions

Buried pipe heat exchanger heat transfer process is actually a complex three-dimensional unsteady heat transfer process, so the unsteady heat transfer process should be adopted for the analysis of research. So the heat exchange efficiency factors affect ground heat exchanger is more, for the convenience of theoretical analysis, the heat transfer model to do the following simplified:

1. Assuming that the soil is uniform, and its physical parameters do not change with temperature changes, namely, with constant physical property.
2. Ignore the influence of the groundwater seepage in the soil, not consider the effect of soil water transfer on heat transfer, heat transfer process in a single heat conduction.
3. Hypothesis model selection of water, pipe material, backfill material and soil thermal physical parameters and heat insulation board is constant, which has nothing to do with temperature.
4. Began to solve, assuming the whole region has the same initial temperature, soil temperature is not affected by the depth, only on the surface under the influence of air convection.
5. Assuming that the buried tube of speed, and temperature on the horizontal direction are uniform.
6. Ignore thermal contact resistance between wall and backfill material, soil and backfill material, heat insulation and the backfill material.
7. With only a single drilling as the research object, not considering the interaction between buried tube well and well.

3.2 Model parameters

Model in this paper in the summer the Nanjing area under the condition of drill hole depth is 120 m of the vertical U-shaped ground heat exchanger, heat insulation plate length of 60 m, 80 m and 100 m distance from the earth's surface, soil influence radius of 3 m, the hole diameter is 150 mm, U-shaped tube diameter is 32 mm, inner diameter of 26 mm, spacing between the two branch pipes is 80 mm. The length of the heat shield and thickness 120 mm × 10 mm respectively.
Model properties include density ($\rho$), thermal conductivity ($\lambda$) and specific heat ($C_p$). Physical parameters of soil is $\rho_1=2082$ kg/m³, $\lambda_1=2.7$ W/(m·K), $C_{p1}=837$ J/(kg·K); Physical parameters of backfill materials is $\rho_2=1989$ kg/m³, $\lambda_2=2.7$ W/(m·K), $C_{p2}=820$ J/(kg·K); Physical parameters for high density polyethylene pipe (HDPE) is $\rho_3=1860$ kg/m³, $\lambda_3=0.44$W/(m·K), $C_{p3}=840$ J/(kg·K); Physical parameters of circulating fluid is $\rho_4=998.2$ kg/m³, $\lambda_4=0.6$ W/(m·K), $C_{p4}=4182$J/(kg·K); Physical parameters of insulation board is $\rho_5=350$ kg/m³, $\lambda_5=0.025$ W/(m·K).

3.3 Grid division

Grid division is directly related to the degree of discrete model, having a big impact on the requirement for computer hardware, computing speed and finally solve convergence. In general, the closer the grid, the higher the precision, but as a result of the computer hardware constraints, to ensure the calculation accuracy, it only processes in the region of the dramatic changes to insure the precision.

Grid division mainly includes in and out of the division of the division of water pipe, pipe (especially need encryption processing bending pipe section, and attention to the quality of the grid), backfill materials division, the division of soil. Grid model figure (part) is as follows:

![Grid division](image)

(a) Buried tube inlet surface meshing  
(b) Single U drilling on surface meshing  
(c) Soil surface meshing  
(d) The division of bending section

Figure 1. Grid divisions.

3.4 Model boundary conditions

The average temperature of Nanjing area soil is 17°C, the side and underside of cylindrical models are set as constant wall temperature wall condition, then all the models of the initial temperature is 17°C. Fluid inlet boundary is defined as the speed of entry, namely the VELOCITY INLET, summer import water temperature is 35°C; Outlet boundary conditions of uncertain, set directly to OUTFLOW; The rest of the face is defined as WALL.
The symmetry plane is set as symmetry plane (symmetry) boundary types, the name of the circulating FLUID is set to FLUID and other areas of the model type is set to SOLID.

When the model conducting Heat Transfer, the influence of heat transfer is an important factor in soil surface convective heat transfer. When soil source heat pump is running, because the different parts of the wind speed in winter and summer as well as the impact of climate conditions is larger, the calculated considering. After calculation can get the average convective heat transfer coefficient of air and soil, the summer is 2.005 W/(m·K).

4 SIMULATION RESULTS AND ANALYSIS

4.1 Effect of different velocity and the different conditions on the thermal short circuits

The well depth of 120 m buried tube heat transfer model in refrigerated condition of the inlet temperature of 308 k, the inlet velocity value of 0.2 m/s, 0.4 m/s, 0.6 m/s, 0.8 m/s, 1.0 m/s and 1.2 m/s, operating conditions, respectively. 1 day, 2 days, 4 days, 6 days, 8 and 10 days is simulated, it is concluded that the outlet pipe temperature Fig. 2.

![Figure 2. The fluid outlet temperature under different flow velocity, different operating conditions.](image)

Fig. 2 is a 120 m depth in constant inlet temperature, different inlet velocity and different conditions of continuous running, the change trend of U-shaped tube outlet temperature. As you can see, in the case of constant inlet velocity, with running time longer, the outlet temperature high, hot short circuit is more and more serious, in thermal efficiency is lower. At the inlet velocity of 0.2 m/s, run 1 and 10 days, outlet temperature is 1.68 °C, increased by 5.68%. As the inlet velocity is bigger and bigger, the outlet temperature of different continuous operating condition changes gradually slow, outlet temperature difference is smaller and smaller, the rate of 1.2 m/s at the inlet and run 1 and 10 days, the outlet temperature is 0.72 °C, grew by 2.36%, so hot short-circuit minimal effect on buried pipe.

When the well depth is constant, with the increase of U entrance velocity in the tube, the trend of the water temperature is gradually increasing. The reason is that inlet velocity is small, U type pipe and soil heat transfer between two branch, branches pipe in heat increase, between tube fluid temperature closer to the soil temperature, short
circuit phenomenon, while short circuit phenomenon is serious, the total heat transfer is more. With the increase of inlet velocity, U-shaped tube of fluid temperature difference between two branches is smaller, and the hot short circuit phenomenon is slow, but the total heat transfer rate is reduced.

4.2 The influence on hot short circuit by adding different length of insulation

The well depth of 120 m buried tube heat transfer model in the inlet temperature of 308 K in refrigerated condition, under the condition of the inlet velocity must be, respectively added 60 m, 80 m and 100 heat insulation board, the outlet pipe temperature is obtained in Fig. 3.

![Figure 3. Inlet velocity is constant, the fluid outlet temperature when adding different heat shield.](image)

From Fig. 3, as the running time longer, not to add insulation board and adding different length of insulation board, the outlet temperature of the heat shield is on the rise trend, and slow rising trend. After adding 60 m insulation board, outlet temperature rather than not to add insulation board was 4.3% higher, visible to add insulation board is not necessarily will slow down the hot short circuit, enhance heat transfer of drilling. Adding heat insulation board 80 m and 100 m board, the outlet temperature difference is very small, outlet temperature compared with not to add insulation board is reduced about 4.8%, considering the economy, adding insulation board exchanger for 120 m deep well, add 80 m heat shield efficiency heat transfer effect is best.

4.3 Economical analysis

Nanjing area are mainly composed of summer cooling load, for drilling depth is 120 m, add 80 m heat shield under summer conditions can make in the U-shaped ground heat exchanger heat transfer ability 4.8% increase. After adding insulation board, drilling depth can be reduced to 115.2 m. source heat pump according to the current market price is about 160 RMB/m drilling, add heat shield a well can save 768 RMB. Insulation board used in the engineering applies more polyurethane, according to a well needed size is 80 m by 120 mm × 10 mm, compared to add 60 m insulation board, calculation of about 300 RMB. Comprehensive drilling cost and ground source heat pump after adding insulation board, a 120 m drilling can save 468 RMB.
In practical engineering, the U-shaped tube after adding backfill materials between two branch pipe is always close together, adding the heat shield can make two branch pipe spacing greater, have the effect of separation and slow heat short circuit on the influence of the heat exchanger. But at the current backfilling technology, drilling as it is difficult to add insulation board in the practical engineering may also be other problems, this work also need further research.

5 CONCLUSION

In this paper, the study based on three-dimensional heat transfer model for vertical U-type buried tube, using the numerical simulation method to Nanjing area in summer conditions ground heat exchanger simulation study. Under the condition of not adding insulation board, compared the different inlet velocity on the heat exchanger, the effects of adding different length are analyzed the influence of insulation surface heat exchanger heat transfer capacity, the conclusion is as follows:

(1) After adding insulation board, the vertical U-shaped ground heat transfer within the tube drilling mainly has two aspects: On one hand: the influence of a heat shield the add heat transfer resistance between the two tubes, effectively reduce the heat flow between the branch pipe, effectively reduce the thermal circuit loss; on the other hand: it is heat shield that will backfill materials within the vertical U-shaped ground pipe drilling into two separate parts, thus reducing the U-shaped buried pipe and heat transfer of backfill materials.

(2) Adding insulation board is not necessarily to improve the heat transfer performance of heat exchanger, also it is not the longer, the more reasonable, to comprehensive consideration of buried pipe heat transfer performance and the economy and then select the best heat insulation plate length. Cooling conditions in the summer, add 80 m heat shield can make the outlet temperature decrease about 4.8%, improves the heat transfer effect of the heat exchanger. While the increased proportion is smaller, it is confirmed that adding a certain length of insulation surface to improve the feasibility of the underground buried pipe heat exchanger heat transfer performance.

6 FUTURE PROSPECTS

Ground source heat pump in the practical engineering run continuously for a long time, the simulation run time is relatively short, but also need to be verified in the practical engineering, further studies are needed. Add the length of the heat shield, selection of material selection and size also need to be further in-depth study. Add heat shield is a kind of measures to slow hot short circuit can also stay in return pipe laying thermal insulation material is also studied. Inhibition of hot short circuit to ground heat exchanger of the study, is beneficial to the improvement of the performance of the heat exchanger heat exchanger, ground source heat pump system is more energy conservation and environmental protection.

REFERENCES


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