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The radiation heat flow field analysis of water medium in Heating Furnace

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ABSTRACT: The fluent is a relatively versatile commercial software in the ansys of fluid software. It has some advantages such as convenient calculation, saving time and effort, good simulation effect, and can be mutually verified. It is widely used in energy and chemical industry. There are some problems in the practical application of Water jacket furnace , such as heating efficiency can't be high, water jacket furnace combustion system life not long, water jacket fireworks system easy to corrode perforation leakage.In this article ,we at the point of how to improve the heating efficiency,and use the Fluent software to do the Simulation. To analyzed and compared the simulation results when heating medium is the of water and ethylene glycol respectively.At the situation of all the radiation model,we will compare which is the best one under the standard ,which concludes media flow and heat transfer. After do the simulation,we can get purpose of Energy saving , Emission reduction and improve the efficiency of Heating furnace.

Keywords: fluent ; heat—transfermedium ; heating furnace; heat transfer efficiency; radiation heating

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I. INTRODUCTION

Heating furnace is the working principle of natural gas burner sprayed high temperature flame directly heating the pyrotechnic tube, high temperature flue gas flow backward, through the flue gas outlet pipe into the smoke box, and then into the atmosphere by the chimney. But the smoke pipe and flue gas outlet pipe near the heat after the increase in density due to decrease in contact with the air tube after the heat transfer temperature drop, and because of increased density and sink, and then heated and then rise, so continue to cycle, To increase the natural gas in the gas coil to achieve the purpose of improving the natural gas air temperature. But should pay attention to the use of Heating furnace furnace overpressure, that is, gas within the gas pipe can not exceed the allowable working pressure.

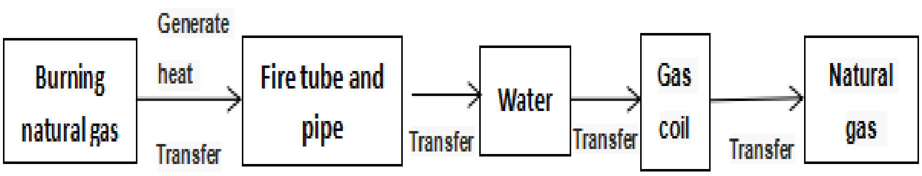


Figure 1 Schematic diagram of heating

The thermal efficiency of the furnace is mainly due to the following factors: the higher the furnace exhaust gas temperature, the lower the thermal efficiency. The greater the excess air coefficient, the lower the thermal efficiency. The greater the loss of chemical incomplete combustion, that is, the more CO and hydrogen in the smoke, the lower the thermal efficiency. The greater the loss of incomplete combustion machinery, the lower the thermal efficiency of the unburned carbon particles in the smoke. The greater the heat loss of the furnace wall, the lower the thermal efficiency. Different intermediate heating media in the radiation model also affect the heating efficiency. In this paper, the heating furnace has the same environment and boundary structure in the simulation process. The meshing and operating environment remain unchanged. The radiation model is used to analyze and compare the two kinds of different heating medium in the cylinder Internal temperature field and flow field status.

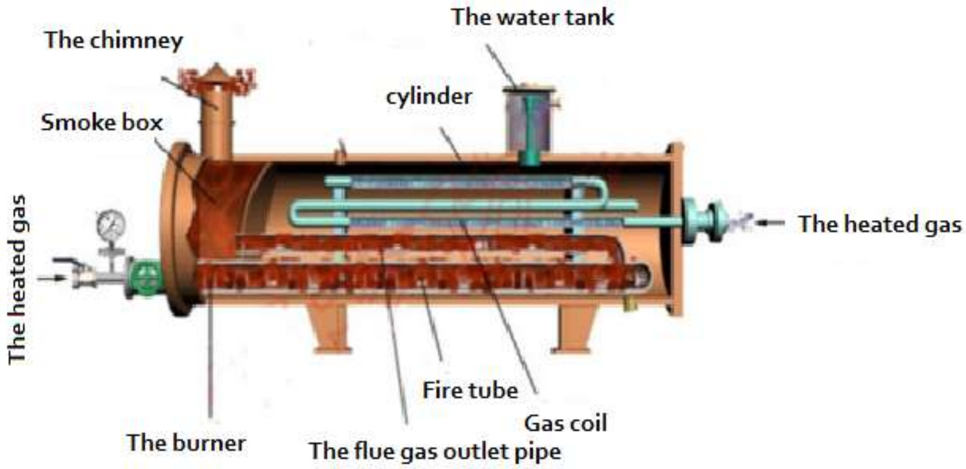


Figure 2 internal system structure of the furnace

In this paper, the low temperature difference is natural convection, so the buoyancy driving flow is used to simulate, and it is suitable for the steady calculation method using Boussinesq model [6]. In the numerical calculation of the natural convective heat transfer in the closed chamber, the Boussinesq assumption is often used to facilitate the treatment of the buoyancy force due to the temperature difference. This assumption is composed of three parts of the viscous dissipation in the fluid is negligible, in addition to the density of other physical properties of the constant, the density is only considered the momentum equation and the volume force of the items, the rest of the density as a constant, The surface temperature is the reference temperature.

1. Mathematical model

For ease of comparison, the same working conditions were used for water and ethylene glycol:

① using the same physical model: steady state, laminar flow, DO radiation model

② keep the same standard atmospheric pressure 101325pa.

③ working temperature are set to 348K.

④ sub-relaxation factors are consistent, Pressure is 0.3, Density is 1, Body Forces is 1, Momentun is 0.7, Energy is 1.

⑤ the initial temperature is set to 300K

⑥ Calculate the heat transfer coefficient with the same calculation formula

The Reynolds number is calculated as follows：

$$\mathrm{Re} = \frac{\rho VD}{\mu} = \frac{VD}{v} = \frac{QD}{vA}$$

Nusselt number calculation:

For heating fluid:

$$Nu_f = 0.023 \mathrm{Re}_f^{0.8} pr_f^{0.4} (t_w > t_f)$$

For cooling fluid:

$$Nu_f = 0.023 \mathrm{Re}_f^{0.8} \mathrm{Pr}_f^{0.3} (t_w < t_f)$$

Where R_f is the Reynolds number of the airflow in the convection tube and Pr is the Prandtl number.

Boundary condition calculation of ethylene glycol:

The heating gas flow rate is set at 1.67 m / s，the pressure of the heated gas is 5.5 MPa, and the inlet and outlet temperatures of the heated gas are 280 and 320 K.respectively, It is assumed that the physical properties in the calculation process are constant. As the medium temperaturechange is small, so that the density and temperature into a linear ratio. Fluid flow is considered to be steady-state laminar flow, so viscous dissipation is negligible. The cylindrical wall is considered to be adiabatic and its heat loss will be ignored using the Boussinesq assumption based on steady-state laminar flow conditions.

According to the actual operating conditions of the heating device, the boundary conditions are calculated as follows: the cylinder wall is regarded as the adiabatic boundary; the average temperature of the fire pipe wall is set to 420K, the average temperature of the flue pipe bundle wall is set to 380K; The condition applies to the boundary of the convective tube bundle and is expressed as:

$$-k_e \frac{\partial T_w}{\partial n} = h(T_w - t_g)$$

Where k_e is the thermal conductivity of the heat transfer medium; n is the normal direction of the wall; Tw is the wall temperature; Tg is the temperature of the heated gas. The average temperature of the heated gas in the first and second pipes was 290 K, and the average temperature of the heated gas in the third and fourth pipes was 310 K. h is calculated by the heat transfer coefficient:

$$h = \frac{Nu \cdot k_g}{d}$$

Where k_g is the thermal conductivity of the gas in the convective tube bundle; d is the diameter of the convection tube; and the Nusselt number (Nu) is calculated by the correlation.

And in the heating pipe inside the specific activities of the situation, the Reynolds number can be described as:

$$Re = \frac{\rho VD}{\mu} = \frac{VD}{\nu} = \frac{QD}{\nu A}$$

V - is the average flow rate (m / s),
D - the diameter of the convection tube (m);
M - is the hydrodynamic viscosity; Q - is the volume flow (m^3 / s);
A - is the cross-sectional area (m^2); u - fluid velocity ; ρ - density kg/m^3 ; m^2/s
p - pressure Pa ; ν - kinematic viscosity m^2/s

While the natural parameters of natural gas at 300 ° are:

300k

	Density Kg/m^3	constant-pressure specific heat kJ/(m^3·k)	Thermal conductivityw/(m·k)	Dynamic viscosity Pa·s	Pr
natural gas	41.8657	1.106720	0.0391	1.23E-5	0.8329

300k

	Gas flow rate m/s	Re	Heat transfer coefficient w/(m^2·k)		
	1.67	215999.782	407.306		

Through the parameters in the table can be obtained:

$$\mathrm{Re} = \frac{\rho VD}{\mu} = \frac{41.8657 \times 1.67 \times 0.038}{1.23E-5} = 215999.782$$

Bring Re into formula (2) ,Pr_f =0.8329,

$$Nu_f = 0.023 \mathrm{Re}_f^{0.8} pr_f^{0.4} = 0.023 \times (215999.782)^{0.8} \times (0.8329)^{0.4} = 395.847249$$

$$h = \frac{Nu \cdot k_g}{d} = \frac{395.8472 \cdot 0.0391}{0.038} = 407.306 w/(m^2 \cdot k)$$

Calculation of water boundary conditions:

300k

	Density Kg/m^3	constant-pressure specific heat kJ/(m^3·k)	Thermal conductivityw/(m·k)	Dynamic viscosity Pa·s	Pr
natural gas	71.25	5.736	0.05396	2.12E-5	0.97

300k

	Gas flow rate m/s	Re	Heat transfer coefficient		

			w/(m²·k)		
	1.67	495781.25	817.84049		

Through the parameters in the table can be obtained:

$$\mathrm{Re} = \frac{\rho VD}{\mu} = \frac{71.25 \times 1.67 \times 0.038}{2.12E-5} = 213129.811$$

Bring Re into formula (2) ,Pr_f =0.97,

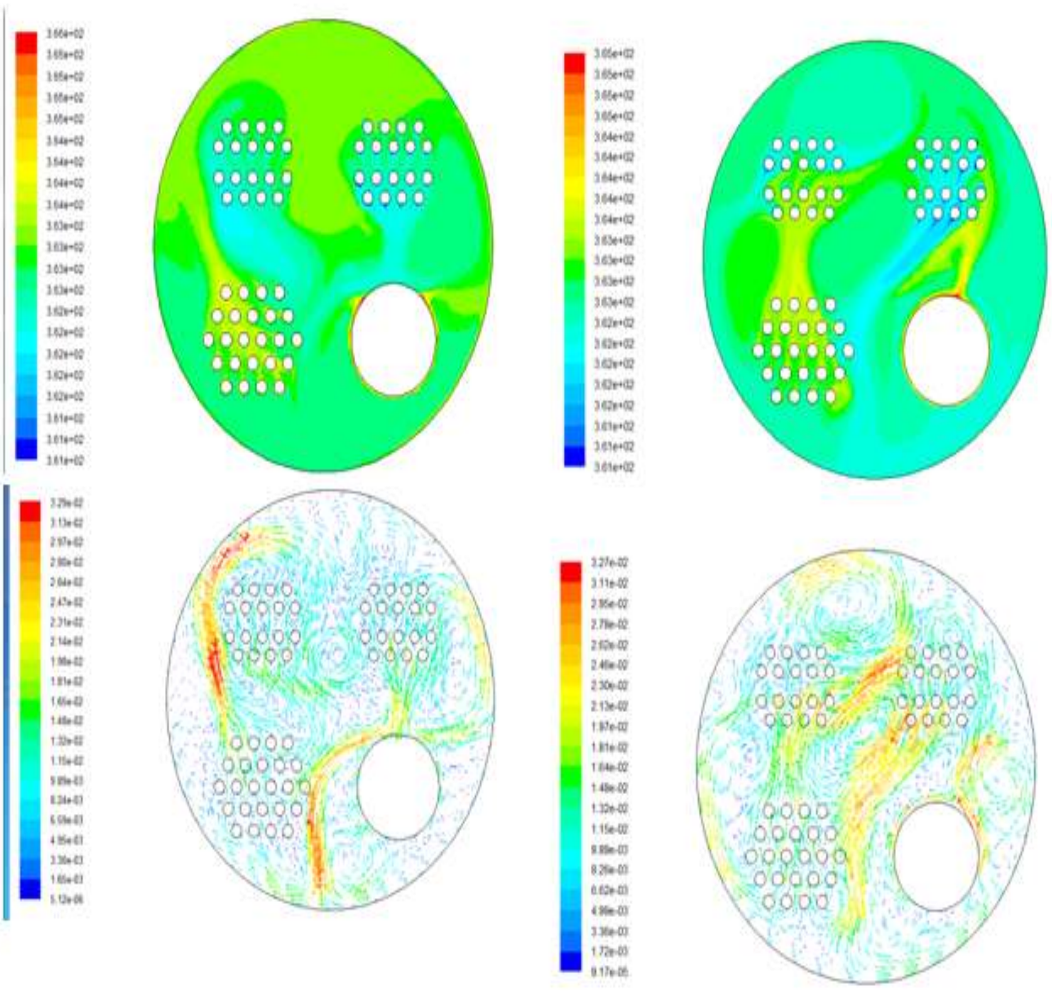
$$Nu_f = 0.023 \mathrm{Re}_f^{\ 0.8}\, pr_f^{\ 0.4} = 0.023 \times (495781.25)^{0.8} \times (0.97)^{0.4} = 817.84049$$

Bring Re into formula (2) ,Pr_f =0.8329,

$$h = \frac{Nu \cdot k_g}{d} = \frac{395.8472 \cdot 0.0391}{0.038} = 817.84049 w/(m^2 \cdot k)$$

II. RESULTS ANALYSIS

From the specific heat capacity, dynamic viscosity, thermal conductivity, density and other physical properties can be seen, water is more suitable than ethylene glycol intermediate medium. And the water as a medium medium cheap, wide range of sources, than the heat capacity. But the water also has shortcomings that the boiling point is low, it is easy to work in high temperature gasification. Although the high boiling point of ethylene glycol, but at a certain temperature, because the viscosity is relatively large, but not conducive to flow, high temperature will be improved. The following analysis from the simulation results:



(a) **(b)**

Figure 3. Before rotating the temperature and speed of the flow field. (*a*) Isothermal contour (K); (*b*) flow vectogram (m/s).

From the simulation of the cloud can be seen, because the boiling point of water is low, when the heat carrier for the water when the local high temperature is easy to cause local high temperature vaporization and other issues. And ethylene glycol can avoid the problem of gasification, you can see the medium when the water there is uneven heat transfer, the obvious temperature stratification phenomenon. It can be seen from the figure because the operating temperature is relatively high, the flow of ethylene glycol is much better than the water, there is a tendency to form a large flow field, and the water flow is chaotic, interference factors are relatively large, and there are many eddy Of the part, hinder the formation of the circulating flow field.

III. CONTRAST ANALYSIS OF RADIATION

The data were obtained when the medium was water, the Absorption Coefficient α was 0.0133, and the Scattering CoefficientαS was 0.0049, which was calculated in the fluent software.

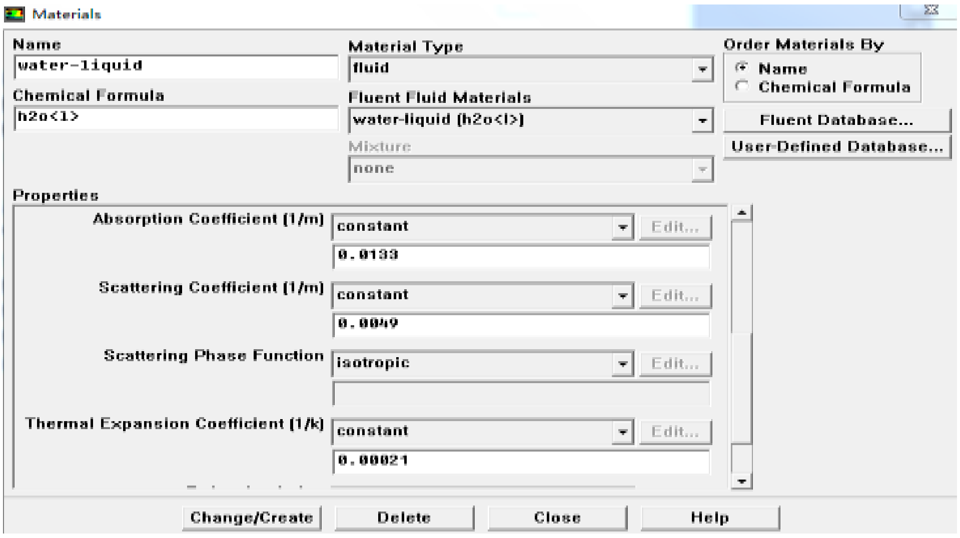


Figure 4 Parameter setting of the intermediate heat medium

Get heat pipe and flue gas bundle heat transfer amount of 668.99493W, radiation is 169.91612W, then the amount of radiation accounted for 25% of heat transfer, in line with the actual situation.

The radiation at each rotation is as follows:

Table 1 Water and ethylene glycol at different temperatures

	280	300	320	340	360	400
Ethylene glycol	14632.342	15121.676	17135.342	17842.453	17985.567	18185.567
water	16573.966	16712.452	16978.324	17101.232	16891.331	16782.452

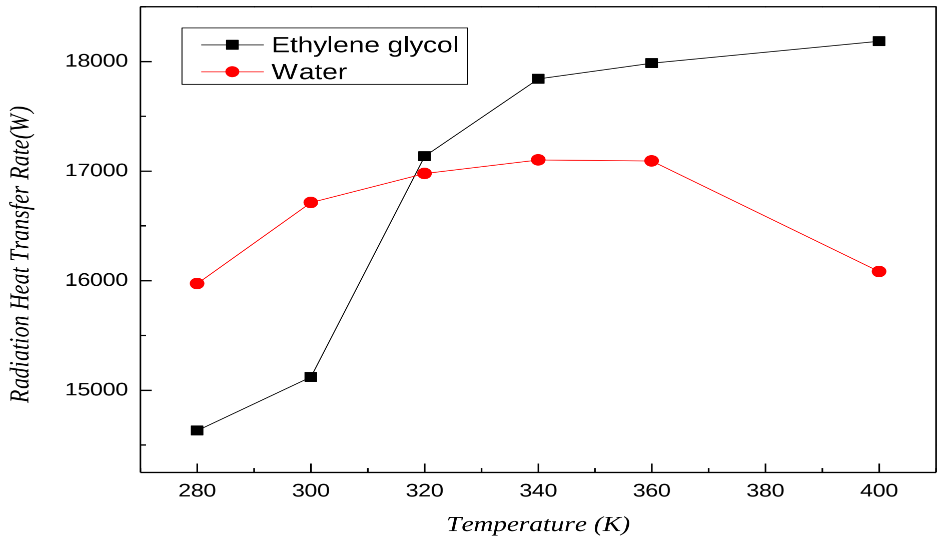


Figure 5 Comparison of the amount of radiation between the two media at different temperatures

It can be seen from the figure that under the same working conditions, the amount of radiation in the water at low temperature is larger than that of ethylene glycol. As the temperature increases, the amount of radiation decreases sharply, and the ethylene glycol is the opposite. Their physical properties, because the low boiling point of water, its work in high temperature conditions easily gasification, high temperature is not conducive to heat transfer, easy to cause heat loss. The ethylene glycol is the opposite, in the case of low temperature, because the viscosity is relatively large, is not conducive to flow, the radiation is relatively small, and high temperature conditions can not only avoid the problem of gasification, and the higher the flow the more smooth flow. Therefore, in discussing the participatory radiation effect of the medium, it can proceed from its physical characteristics, and the participant radiation effect of water is better than that of ethylene glycol at low temperature. At high temperature, the participant radiation effect of ethylene glycol is better than water .

IV. CONCLUSIONS

(1)The heating medium based on the physical properties , according to the heating principle , we analysis the factors which influencing the heating efficiency , and from the viewpoint of economy and practicability we propose how to improved the heating efficiency .

(2) Under the same radiation model, when the temperature is greater than 100 °, the thermal efficiency of ethylene glycol is better than water. While the temperature is lower than 100 °, water is selected as the best heating medium. In the actual work, wu should according the actual situation, select the appropriate heat medium.

Declaration of interest

The researcher declare that the manuscript have no competing interests including any financial, the personal, or organizations. and no conflicts with the study of any individual economic interests and non-economic interests and any direct or between obligation and responsibility. within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence the present .As the researchers of this project, I economic interests above statement is true.

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