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Laminar natural convection heat transfer characteristics of molten salt around horizontal cylinder

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Abstract

In order to obtain the laminar natural convection heat transfer mechanism of molten salt, the natural convection heat transfer of multi-component molten salts around a cylinder with different diameters was studied by simulation. The result showed that the natural convective heat transfer of molten salt in the Rayleigh number range of 1.57×10^{-2} -2.03×10^{6} cound be predicted by Fand's correlation that took the viscous dissipation into consideration, in addition to Prandtl and Rayleigh numbers. With the increasing in Rayleigh number, the effect of viscous dissipation decreased, so the other correlations that neglected the effect of viscous dissipation cound also predict the natural convection of molten salt well. Those results cound be a foundation for predicting the natural convection heat transfer of molten salt.

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Keywords: Natural convection; Numerical simulation; Boundary layer; Viscous dissipation ;

1. Introduction

In recent years, renewable energy utilization, especially solar thermal power generation, has gradually become research hot due to the energy shortage and environmental pollution. Thermal energy storage (TES) is a key process for solar thermal power production, which can mitigate the changes in solar radiation during transient weather cond-

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Nomenclature

A	heat transfer area, πdl, m^2
c_p	specific heat capacity, J/(kg·K)
d	cylinder diameter, mm
$d_{0.1}$	cylinder diameter is 0.1 mm
d_1	cylinder diameter is 1 mm
d_{10}	cylinder diameter is 10 mm
h	convective heat transfer coefficient, W/(m^2·K)
l	equivalent diameter, m
Q_{conv}	the amount of heat transfer of natural convection, W
q	heat flow density, W/m^2
ft	Feet, 1ft=304.8mm
T_m	qualitative temperature, K
T	temperature at a point in space, K
T_s	cylindrical surface temperature, K
T_∞	infinite space temperature, K
ΔT	temperature difference in the thermal boundary layer, K
a	thermal diffusivity, m^2/s
β	coefficient of cubical expansion，$(\rho-\rho_\infty)/\rho(T_\infty-T)$, 1/K
δ_t	thermal boundary layer thickness, mm
λ	thermal conductivity, W/(m·K)
μ	dynamic viscosity, kg/(m·s)
ρ	density, kg/m^3
Ge	Gebhart number, $gl\beta/c_p$
Gr	Grashof number, $gl^3\beta(T-T_\infty)/v^2$
Nu	Nusselt number, hl/λ
Pr	Prandlt number, v/a
Ra	Rayleigh number, $gl^3\beta(T-T_\infty)/av$

-itions or time-shifting. Two-tank thermal storage of molten salt is a relatively mature TES technology, which has been used in the running solar thermal power station. However, such a thermal storage technology can cause a huge initial investment and high maintenance cost. Single-tank thermocline storage has the properties of the lower initial investment and operation maintenance cost [1], and shows the good application prospect. However, it is difficult to separate the hot and cold fluids by thermocline in the TES of single tank. If a heat exchanger is immersed inside a single-tank, heat energy can be stored in or released from the single-tank through the immersed heat exchanger. During this process the heat transfer around the heat exchanger is the natural convection heat transfer. Therefore, research of natural convection heat transfer of molten salt is very important for designing a single-tank with a heat exchanger immersed in it. So the study of natural convective heat transfer of multi-component molten salts at different range of Rayleigh number (Ra) is very important.

At present, a few researchers have studied the natural convective heat transfer of molten salt. Qian *et al* [2-3] studied the natural convection of fluoride molten salt in cavity using numerical simulation. The result showed that the local Nusset number (Nu) changed depending on the different Ra number, and the natural convection heat transfer was enhanced with the increasing of the Ra number. In addition, Zuo *et al* [4] studied the thermal storage in single-tank and found that the natural convection heat transfer of molten salt had a certain influence on TES. Zhang *et al* [5] researched the mixed convection heat transfer of molten salt in the solar collector, and fond the similar result. Lu *et al* [6] analyzed the natural convection heat transfer of $LiNO_3$ using Joule heating method with fine wire, and found that natural convection heat transfer of $LiNO_3$ fit well with Fand's correlation that included the influence of viscosity dissipation.

In this paper, the natural convection heat transfer of Hitec salt was studied by simulation at a wide range of Ra