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Research on performance of the coupled heat and mass transfer in ground source heat pump system

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Abstract

Environmental improvements require waste minimization, reduced air pollution from vehicles, distributed energy generation, and reduction of greenhouse gas emissions. Utilizing solar energy, geothermal energy, waste heat and exhaust heat as the heat source to complete the refrigerating and air conditioning process is an important way to develop more efficient utilization of energy. Therefore, ground source heat pumps (GSHP) driven by ground heat have outstanding energy saving effect since they are operated at high coefficient of performance (COP) without air pollution. GSHP is widely developed because of its outstanding advantages in energy conservation and environmental protection. Soil heat used by GSHP is pollution-free. The development of GSHP is restricted by many factors, and the key one is the heat and mass transfer performance of ground heat exchanger (GHE). This study takes GHE as the object and then researches its heat and mass transfer performance. The three-dimensional numerical model of the coupled heat and mass transfer is established so as to analysis the heat and mass transfer under different initial soil temperatures and soil moisture contents. The dual purpose of this study is to evaluate the numerical model of the coupled heat and mass transfer and to analyze the heat and mass transfer performance.

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Keywords: Ground source heat pump; Heat and mass transfer; Coupled performance

1. Introduction

A series of measures like waste minimization, reduced air pollution from vehicles, distributed energy generation, and reduction of greenhouse gas emission are required for environmental improvements. CO_2 and SO_2 emissions in

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China have been the second and the first over the world [1].The average building energy consumption accounts for about 37% of the total energy consumption in the world, and about 40% in China [2]. Utilizing solar energy, geothermal energy, waste heat and exhaust heat as the heat source to complete the refrigerating and air conditioning process is an important way to develop more efficient utilization of energy.

The GSHP driven by ground heat has a great energy-saving effect since it is operated at high coefficient of performance (COP) without air pollution [3]. The application and development of renewable energy like geothermal energy are actively advocated by the Chinese government [4]. Firing coal is still the main pattern in energy utilization in China, therefore leads to a severely polluted environment. The best way is to strengthen the utilization and development of renewable energy sources and to improve the energy saving technology. The research on ground source heat pumps is absolutely necessary, for it saves land resource and the soil temperature is steady [5-7].

Consisting of solid, liquid and gas, soil is a kind of porous media. Both heat conduction and heat convection exist in the heat transfer process [8]. The numerical model of the coupled heat and mass transfer is evaluated and the heat and mass transfer performance is analyzed in this paper. Ground source heat pump is strongly influenced by the thermophysical parameters of soil. This study mainly analyzes the heat and mass transfer performance under different initial soil temperatures and soil moisture contents.

Nomenclature

GSHP	ground source heat pump
COP	coefficient of performance
GHE	ground heat exchanger
a	thermal diffusion coefficient (m^2/s)
r	distance from the center of the borehole (m)
T	soil temperature at the time of τ with r meter from the center of the borehole (K)
P	pressure (Pa)
c	specific heat capacity (J/(kg·K))
D	mass diffusivity coefficient (m^2/s)
R	gas constant (J/(mol·K))
H	latent heat of vaporization (kJ/kg)
v	velocity of water through the pipe (m/s)
t	fluid temperature through the pipe (K)
l	length of the vertical GHE (m)
Greek symbols	
τ	elapsed time of GHE (s)
ε	soil porosity
θ	soil moisture content
ρ	density (kg/m^3)
λ	thermal conductivity of soil (W/(m·K))
Subscripts	
w	water in soil
v	water vapour in soil
s	solid phase in soil
w	liquid water at a moisture gradient in unsaturated soil
wT	liquid water at a temperature gradient in unsaturated soil
in	inlet
out	outlet