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Investigation of evacuated tube heated by solar trough concentrating system

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Abstract

Two types of solar evacuated tube have been used to measure their heating efficiency and temperature with fluids of water and N_2 respectively with a parabolic trough concentrator. Experiments demonstrate that both evacuated tubes present a good heat transfer with the fluid of water, the heating efficiency is about 70–80%, and the water is easy to boil when liquid rate is less than 0.0046 kg/s. However, the efficiency of solar concentrating system with evacuated tube for heating N_2 gas is less than 40% when the temperature of N_2 gas reaches 320–460 °C. A model for evacuated tube heated by solar trough concentrating system has been built in order to further analyze the characteristics of fluid which flow evacuated tube. It is found that the model agrees with the experiments to within 5.2% accuracy. The characteristics of fluid via evacuated tube heated by solar concentrated system are analyzed under the varying conditions of solar radiation and trough aperture area. This study supports research work on using a solar trough concentrating system to perform ammonia thermo-chemical energy storage for 24 h power generation. The current research work also has application to solar refrigeration.

Keywords: Solar energy; Trough; Concentrating system; Evacuated tube

1. Introduction

Concentrating solar thermal technologies offer a promising method for the large scale use of solar energy. Three are three main solar thermal concentrator technologies [1,2]: central receivers which have been applied in many power plants since 1965; parabolic troughs which contribute the greatest share of installed capacity with 345 MW_e of natural gas assisted power plants operating for up 15 years on a fully commercial basis in Southern California; and paraboloidal dishes such as developed by Australian National University for large scale solar thermal power system. Australian National University also have developed a novel combined heat and power solar system (CHAPS) for domestic power and hot water [3], which is based on a concentrating trough system. According to prior research on dissociating ammonia for energy storage, the Solar Thermal Group at the Australia National University plans to use a trough concentrator as heating resource on research

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Nomenclature

A_a	absorber area (m^2)
A_r	receiver area (m^2)
A_{shade}	the shade area to absorber (m^2)
B	the width of parabolic trough mirror (m)
C_p	specific heat at constant pressure (J/kg K)
COP	coefficient of performance
D	outer diameter of glazed glass (m)
D_o	outer diameter of receiver tube (m)
D_i	inter diameter of receiver tube (m)
F'	collector efficiency factor
F_R	heat removal factor
h_w	convective heat transfer coefficient with glass tube (W/m^2 K)
$h_{f,i}$	average heat transfer coefficient between fluid and receiver (W/m^2 K)
I_b	beam irradiation (W/m^2)
K	glazed glass thermal conductivity (W/m K)
K_i	receiver thermal conductivity (W/m K)
L	length of parabolic trough mirror
$\dot{m}$	mass of fluid flow (kg/s)
Nu	Nusselt number of air
Nu_m	Nusselt number of fluid in receiver
Pr	Prandtl number
Q_u	effective energy obtained from receiver (kJ)
Re	Reynolds number of air
Re_d	Reynolds number of fluid in receiver
T_a	temperature of ambient (°C)
T_i	temperature of fluid input (°C)
T_o	temperature of fluid output (°C)
T_p	temperature of glazed glass (°C)
T_r	temperature of receiver (°C)
U_O	heat transfer coefficient from fluid to ambient air (W/m^2 °C)
U_L	solar collector heat loss coefficient (W/m^2 °C)

Greek symbols

ρ	mirror reflectance
$\tau\alpha$	transmittance–absorptance product
γ	collector optical factor
η	efficiency of solar concentrating system

work of dissociating ammonia, so as to apply this technology for more fields of solar energy. This paper focuses on both experimental study and simulated calculation about solar trough concentrator system when evacuated tubes and different fluid medium (such as water and N_2) are adopted. Based on these research works, the further optimized design and experimental works about dissociating ammonia will be carried out. Also the research works of trough concentrating system will help us in application of solar solid refrigeration due to its powerful solar energy input.

2. The testing system and heating efficiency

Fig. 1 shows schematic diagram of trough concentrating system heating evacuated tube. Main features are a parabolic curved mirror (1), solar collector (2, or evacuated tube), fluid input tube (3), fluid output tube (4)