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Experimental investigation of heat absorption of different solar pond shapes covered with glazing plastic

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Abstract

This study investigated different shapes of solar ponds at two salt gradients. Ponds of rectangular and circular shapes with similar cross sections and volumes were examined. The results indicated that, with respect to shadow areas formed in both ponds, the maximum temperature of rectangular and circular solar ponds reached 74 °C and 71 °C, respectively, as a result of the smaller area of the shadow created in the rectangular solar pond. Moreover, the glazing plastic cover prevented heat from escaping the pond. This caused the temperature between the UCZ in both solar ponds and ambient to be 13 °C at the end of the test, hence causing a reduction of temperature difference from top to bottom of the ponds. Likewise, it was concluded that dusty weather negatively affected the efficiency of solar ponds and decreased the temperature in solar ponds in such a way that with weather returning to the normal condition (as it was before dust), the temperature of pond hardy went back to what it was after several days. On the other hand, plastic covers were applied to avoid turbidity of water in the pond as well as avoiding the entry of dust into the water, proving to have a positive effect on the preservation and sustainability of solar ponds.

Keywords: Solar pond; Salt gradient; Geometry effects; Shadow; Glazing plastic cover; Dusty weather

1. Introduction

Due to the recent climate changes in Iran, such as the shortage of rainfall leading to shortage of water resources and subsequently to a decline in producing hydroelectricity, as well as the unique solar radiation condition dominating almost the whole geography, the Iranian government concluded to pay more attention to production of energy from renewable sources including solar energy. The southwest of Iran is an appropriate region for exploiting this type of energy.

Dezful, a city in southwestern Iran, with a longitude of 48 and latitude of 32, enjoys a hot climate and a high solar radiation in spring and summer. The temperature on some sunny days of the year (over 13 h) reaches 50 °C. Nevertheless, the existence of sever regional dust storms in recent years has had negative effects on the efficiency and effectiveness of solar systems and plans, calling for further investigations and research.

Solar pond is one of the relatively modern technologies in the new energy domain, collecting considerable amount of solar thermal energy in a short time and storing for a long time. There are several types of solar ponds, which a salt gradient solar pond helps to store solar energy at the bottom of the pond. In this study, the experiment was

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Nomenclature

d	half distance between the centers of two circles (m)
D	diameter of circle
h	hour
L	length of the rectangle (m)
l	depth (m)
n	number of day
R	radius of circle
S_{shadow}	the area of shadow (m^2)
S_{sun}	the area of sun (m^2)
W	width of the rectangle (m)
z_r	refraction angle

Greek symbols

α	angle of radiation to pond
γ	angle relative to the geographic position Pond
δ	the declination angle
η_{Ref}	the refraction coefficient
θ_i	zenith angle
θ_v	incidence angle
Ψ	angle of latitude
ω	hour angle in degree

Subscripts

LCZ	lower convective zone
NCZ	none convective zone
UCZ	upper convective zone

conducted on this type of solar pond. Fig. 1 illustrates the solar pond, which consists of three layers of saltwater with different depths. The first layer, the upper convective zone (UCZ), is a thin layer of saltwater that has the same salt content as seawater. The second layer, the non-convective zone (NCZ), has a variable concentration, as its concentration profile is linear and increases from top to bottom. This layer, due to its variable concentration, prevents free dislocation of the heat, and the heat exchange only occurs by conduction. Hence, this layer acts as a heat insulator. The bottom layer is called the lower convective zone (LCZ) and has a very high concentration near the saturation capacity.

Due to the high concentration gradient from top to bottom, the convection current from hot water at the bottom and cold water at the top is prevented. This concentration gradient is obtained by using a suitable kind of salt, such as sodium chloride, with high concentration at the bottom of the pond and low concentration at the top of the pond. The temperature of LCZ depends on some factors: intensity and duration of solar radiation, thickness of NCZ, ambient temperature, and stability of the salt gradient.

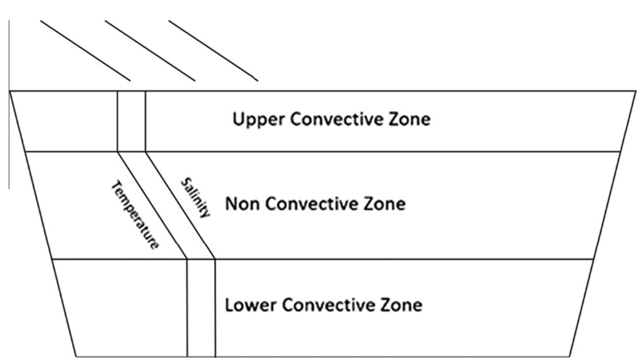

Fig. 1. Schematic figure of salt gradient solar pond.

Since the area of created shadow is an effective factor on thermal performance of solar ponds, especially small ones, it should be considered in the analysis.

Zangrando (1980) suggested a simple method for establishing salt gradient in solar ponds. Duffie and Beckman (1980) explained the relations among radiation angles and solar radiation. Jaefarzadeh (2004) numerically investigated the thermal behavior of a small salinity-gradient solar pond with wall shading effect by modeling the heat conduction equation for the NCZ. Jubran et al. (2004) presented a numerical simulation of the convective layers of solar ponds and concluded that the angle of the pond wall has a significant effect on the activity of the convective layer. Ould Dah et al. (2010) experimentally investigated the stability of a mini solar pond. Their results indicated that the average of daily temperature, after 20 days of activity, reached 54 °C in LCZ and the average of temperature changes recorded in LCZ and UCZ was 27 °C. Velmurugan and Srithar (2008) examined the scope and prospects of solar ponds and found out that turbidity and wall shading effect reduce solar pond performance. Wu et al. (2009) suggested a mathematical procedure to estimate the solar absorbance of shallow water pond and concluded that solar absorption is related to incidence angle, water depth, beam spectra, diffused radiation, roughness, and brightness. Cherubini et al. (2010) evaluated the stability of the salt concentration gradient in solar ponds. El-Sebaii et al. (2011) studied the history of the solar ponds and concluded that the temperature, salinity and density in UCZ and LCZ are almost consistent, increasing with depth in NCZ. Hua et al. (2011) numerically studied the logical dynamic behavior without convection in salt gradient ponds. The paper mainly deals with the determination of stability boundaries of NCZ. Kurt et al. (2006) numerically and experimentally investigated the efficacy of a salt gradient solar pond of sodium carbonate