EXPERIMENTAL STUDY OF CLOSE-PACKED EVACUATED-TUBE COLLECTOR UNDER THE WEATHER CONDITION OF NORTH CHINA

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Abstract

Evacuated-Tube Collector (ETC) plays an important role in the efforts against energy shortage and climate change in China, where it is mainly used for solar water heating and the market share is the largest all over the world.

In this paper, an experimental study was implemented for the close-packed ETC, tube spacing of which is just 3mm. Also an ordinary ETC was studied for comparison. The experimental system was established in Tianjin, north China. Tianjin is located in the climate division of cold zone, a typical region in China for the application of solar water heating.

Experiment was conducted all through the year, the gained heat as well as the collector efficiency were worked out. The results from the experiment revealed that the close-packed ETC efficiency is 25-30% higher than that of ordinary ETC. This improvement on the efficiency is valued for the solar water heater industry in China. Also in this paper simulation was carried out to study the influences of wind speed to the mechanics performance of closed packed ETC, to provide guide to the engineering and installation.

1. Introduction

Great works have been made on the selective coating, tubular length and reflecting panel to improve the performance of ETC. Also it is effective to install more evacuated-tubes to the storage tank. However, this is restricted by the manufacturing process of the tubular holes and the structure design of the solar water heater [1] [2].

It is obvious that radiation leaked from tube spacing of the closed-packed ETC is much less than normal product. Also insulation of the closed-packed ETC is improved due to one-step foaming procedure [3] [4].

To study the performance of closed ETC, a experimental system as established on the roof of a building in Tianjin University. Tianjin belongs to the cold zone in China, the other 3 climate zones in China including extreme cold zone, hot summer and cold winter zone and hot summer and warm winter zone.

Figure 1 shows the closed-packed and ordinary ETC used in the experiment, and the parameters of the closed packed ETC are listed in table 1.

The principle followed in the experiment is relative Chinese National Standard [5].

Fig. 1: Close-packed ETC (L.) and ordinary ETC (R.) used in the experiment

Tab. 1 Parameters of the closed-packed ETC

Parameter	Value
Quantity of evacuated tube	24
Diameter of outside glass tube	58
Thickness of outside glass tube	1.7
Diameter of inner glass tube	47
Thickness of inner glass tube	1.5
Length of glass tube	1800
Coating absorptivity	0.86
Coating reflectivity	0.08

2. Findings from the experimental study

Experiment was carried out in certain days in May and June, gained heat as well as the collector efficiency of the closed-packed ETC was worked out. For comparison, the ordinary ETC was tested. Table 2 shows some measured data including water temperature and radiation level, which is extremely important for the experiment.

Figure 2 and 3 show gained heat and efficiency of closed-packed ETC as well as ordinary ETC. It is obvious that both parameters were improved. Under the certain radiation level, the gained heat of closed-packed ETC is 13.5%-18.6% higher than ordinary one.

Compared with normal ETC, the closed-packed ETC increases the collector efficiency to an extent of 25-30%.

Tab. 2 Daily efficiency of the closed-packed ETC from the experiment

Date	**Initial water temp (℃)**	**Final water temp (℃)**	**Radiation (MJ/m^2)**	**Collector efficiency**
May 22, 2010	31.58	67.30	14.89	0.614
May 23, 2010	34.48	71.35	15.42	0.612
May 24, 2010	36.30	68.93	13.97	0.597
Jun 12, 2010	33.23	65.27	13.80	0.594
Jun 13, 2010	36.27	63.80	12.25	0.575

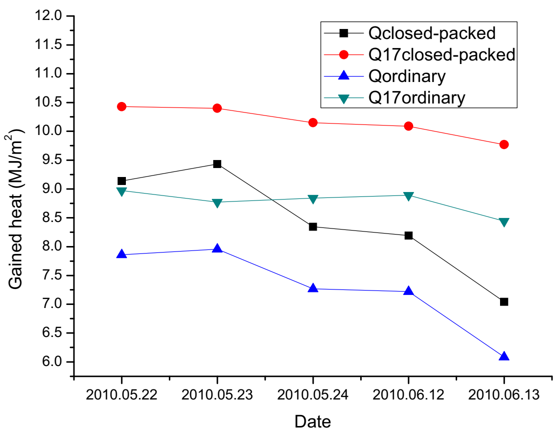

Fig. 2: Gained heat of close-packed and ordinary ETC

Fig. 3: Efficiency of close-packed and ordinary ETC

3. Simulation study to the pressure distribution under different wind speed

The flow in the collector obeys the mass conservation equation, energy conservation equation and momentum conservation equation (equation 1, 2 and 3).

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \quad \text{(eq. 1)}$$

$$\begin{aligned}
\frac{\partial(\rho u)}{\partial t}+\frac{\partial(\rho uu)}{\partial x}+\frac{\partial(\rho uv)}{\partial y}+\frac{\partial(\rho uw)}{\partial z}&=-\frac{\partial p}{\partial x}+\frac{\partial \sigma_{xx}}{\partial x}+\frac{\partial \sigma_{yx}}{\partial y}+\frac{\partial \sigma_{zx}}{\partial z}+F_x \\
\frac{\partial(\rho v)}{\partial t}+\frac{\partial(\rho vu)}{\partial x}+\frac{\partial(\rho vv)}{\partial y}+\frac{\partial(\rho vw)}{\partial z}&=-\frac{\partial p}{\partial y}+\frac{\partial \sigma_{xy}}{\partial x}+\frac{\partial \sigma_{yy}}{\partial y}+\frac{\partial \sigma_{zy}}{\partial z}+F_y \quad \text{(eq. 2)} \\
\frac{\partial(\rho w)}{\partial t}+\frac{\partial(\rho wu)}{\partial x}+\frac{\partial(\rho wv)}{\partial y}+\frac{\partial(\rho ww)}{\partial z}&=-\frac{\partial p}{\partial z}+\frac{\partial \sigma_{xz}}{\partial x}+\frac{\partial \sigma_{yz}}{\partial y}+\frac{\partial \sigma_{zz}}{\partial z}+F_z
\end{aligned}$$

$$\frac{\partial(\rho T)}{\partial t}+\frac{\partial(\rho uT)}{\partial x}+\frac{\partial(\rho Tv)}{\partial y}+\frac{\partial(\rho wT)}{\partial z}=\frac{\partial}{\partial x}(\frac{k}{c_p}\frac{\partial T}{\partial x})+\frac{\partial}{\partial y}(\frac{k}{c_p}\frac{\partial T}{\partial y})+\frac{\partial}{\partial z}(\frac{k}{c_p}\frac{\partial T}{\partial z})+S_T \quad \text{(eq. 3)}$$

The FLUENT Flow Modeling software was used to to investigate the mechanics performance of closed-packed ETC, which raises more requirement in engineering and installation, extremely under high wind speed, pressure distribution was also simulated with the software, and the results are shown in figure 4.

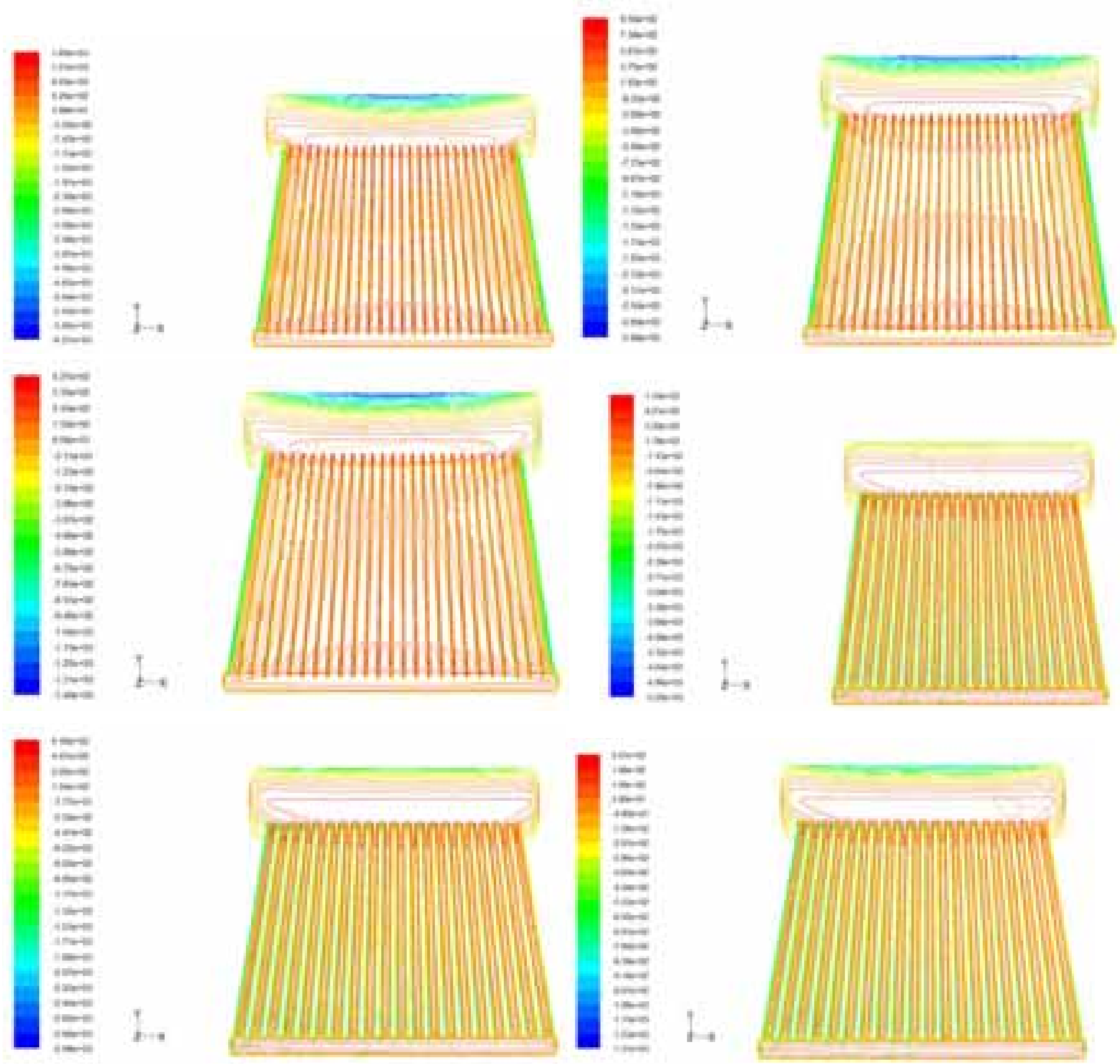

Fig. 4: Pressure distribution at different cases: u.l. tube center spacing 61mm, wind velocity 40m/s; u.r. center spacing 61mm, velocity 30m/s; m.l. center spacing 61mm, velocity 20m/s; m.r. center spacing 81mm, velocity 40m/s; l.l. center spacing 81mm, velocity 30m/s; l.r. center spacing 81mm, velocity 20m/s)

Figure 4 clearly indicates that the pressure on the surface of closed-packed ETC (center spacing 61mm) increases apparently with the increasing speed, much stronger than the ordinary one, for the wind found a way in the wide spacing. However, except for the extreme weather condition, the influences of wind speed to the performance of closed-packed ETC can be neglected.

4. Conclusions

To study the performance of closed-packed ETC, experimental study as well as CFD simulation was carried out. The simulation study was done at wind velocity of 20, 30 and 40m/s, respectively, and the results indicate that the extra evacuated tube of the closed-packed ETC has only little effect to the mechanical properties of the unit, thus can be neglected during installation.

The experimental study indicated that the closed-packed ETC improved the heat collecting characteristics greatly compared with normal ETC, and the collector efficiency is increased by 25-30%.

Reference

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