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Influence of installation mode and latitude on collector performance

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Abstract

Using transient simulation software polysun to simulate flat plate collectors in different inclination and azimuth, analyses outlet water temperature and solar radiation projected on collectors. Results show, in the summer, the collectors face east with 45° installation angle, can better absorb solar radiation, the outlet water temperature of collector is highest, while face south with 90° is the worst. In contrast to this, in winter, face east with 90 ° installation angle and face south with 90 ° installation angle are the best and worst for six different inclination and orientation .In Guangzhou, outlet temperature of collectors is steady and higher at 25° installation angle and face south, irradiation projected on collectors is irregular.

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Keywords: solar energy; optimum tilt; installation orientation; collector performance

Nomenclature

$\dot{m}$	quality of work flow collector unit time（kg/h）
U_L	heat loss collector total(%)
F'	collector efficiency factor
C_p	specific heat capacity at constant pressure of refrigerant(J/(kg·℃))
T_f	average temperature of the fluid in the collector (℃)
T_a	environment temperature (℃)
A_C	effective aperture area of collector S is solar radiation absorption(m2)
S	solar radiation absorption(kWh)
I_b	direct solar radiation intensity (W/m2)
I_d	scattering intensity of solar radiation (W/m2)

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I_g	ground reflected solar radiation intensit (W/m2)
R_b	ratio of direct solar radiation intensity projected on inclined plane and horizontal plane
d	intersection angle between sun light and earth's equatorial plane
ω	sun angle displacement from the sun at noon
L	latitude
$(\tau\alpha)b$	product of transmittance and absorbance for transparent cover that is direct
$(\tau\alpha)d$	product of transmittance and absorbance for transparent cover that is scattering
$(\tau\alpha)g$	product of transmittance and absorbance for transparent cover that is surface reflection
G	total solar radiation converted on a tilt plane(kJ/(h·m^2))
F_R	collector heat transfer factor
η	instantaneous collector efficiency（%）

1. INTRODUCTION

Due to the earth's rotation and revolution, there are different irradiation energy in different regions, different times, different seasons and different direction of slope. In order to make collectors can collect most radiant heat 他 , they should be installed vertically with incident light ,but automatic tracking system to achieve this function is complex, costs of manufacture and maintenance are expensive. Taking building layout and use of space constraints into account, a lot of solar collectors are tilt arrangement. Solar radiation intensity, heat absorption of collector and collector performance are affected by many parameters ,there are complex relationship, cannot be simply represented by mathematical formula, but different place installation direction and inclination angle have a great impact on collector efficiency and collected energy .Camelia Stanciu, Dorin Stanciu etal. using three different models of flat plate collector, calculated optimal installation angle in different geographic locations, at different time in annual , the conclusion are based on the local latitude, the installation angle increases 10°~15° in winter and reduces 10 °~15°in summer[1][2] .In Dubai[3], people had a study on installation angle -20＜β＜90 and azimuth angle-90＜γ＜90,the results showed optimal installation angle is 22°,this is close to the local latitude 24.4°.Foremost, installation angle reduces gradually from the south , the local optimum installation angles change from -9°in June to 52°in November . Thus proposed to adjust the installation angle at least two times a year. At present, according to the design practice in our country, collector installation angle is bigger 10°than the local latitude when used mainly in Winter and less than 10°In summer .latitude of Lanzhou is 36°,so the reasonable installation angle used in winter should be 46°, and 26°in summer, the best orientation is south. In order to verify the rationality of the installation, provide the basis for installation mode which is restricted by building space and layout. in this paper, taking the characteristics of solar radiation, heat exchange of collector and influence of collector performance parameters as the theory basis, use solar simulation software polysun to simulate collector performance under different installation modes, and choose the most suitable mode, which is economy, practicality, convenient, and provide a theoretical basis and effective data for the utilization of solar energy in the practical engineering.

2. METHODS

The systemshown in Fig. 1, which is composed of flat plate collectors, circulating water pump, the heat collection water tank, pipeline and other parts. Collector area is 10 m^2; the flow of water is 1m^3/h, set inlet water temperature of collectors according to the local annual average temperature, 12 C. Then, the relationship between the outlet temperature of collectors, installation parameters and the amount of solar radiation is the major content of our study. The following is performance equation of heat collector [4-6]

$$\frac{T_{fo}-T_a-S/U_L}{T_{fi}-T_a-S/U_L}=\exp(-\frac{U_L A_C F'}{\dot{m}C_p}) \qquad (1)$$

and

$$S = I_b R_b(\tau\alpha)_b + I_d(\tau\alpha)_d(\frac{1+\cos\beta}{2}) + \rho_g I_g(\tau\alpha)_g(\frac{1-\cos\beta}{2}) \quad (2)$$

$$R_b = \frac{\cos(L-s)\cos d\cos\omega + \sin(L-s)\sin d}{\cos L\cos d\cos\omega + \sin L\sin d}$$

Collector heat transfer factor F_R is the ratio of output energy of collector of actual and assuming the heat absorbing plate in medium inlet temperature, represented by the formula[7][8]:

$$F_R = \frac{\dot{m}C_p(T_{fo}-T_p)}{A_C[S-U_L(T_{fi}-T_a)]} = \frac{\dot{m}C_p}{A_C U_L}[\frac{[S/U_L-(T_{fi}-T_a)-[S/U_L-(T_{fo}-T_a)]}{S/U_L-(T_{fi}-T_a)}] = \frac{\dot{m}C_p}{A_C U_L}[1-\frac{S/U_L-(T_{fo}-T_a)}{S/U_L-(T_{fi}-T_a)}) \quad (3)$$

The instantaneous collector efficiency equation is as follows:

$$\eta = \frac{Q_U}{A_c I_T} = \frac{\dot{m}C_{pf}(T_0-T_i)}{A_c G} = F_R(\tau\alpha)_n - F_R U_L\frac{T_i-T_a}{G} \quad (4)$$

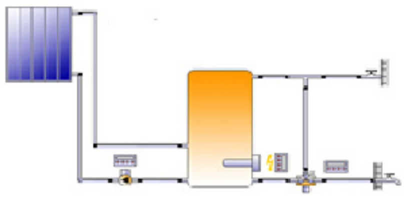

Fig. 1. Diagram for collectors terminal of solar heating system

Solar radiation is related with direct solar radiation intensity; diffuse solar radiation intensity on horizontal surface, declination, latitude L, slope inclination angle β and other factors. Solar radiation exposure to the surface of collectors how much can be absorbed are closely related with the collector structure, layout, performance. Orientation, inclination and latitude are important and variation parameters, so this paper analyzed the impact which is caused by orientation and inclination in different latitude of Lanzhou and Guangzhou.

Equation 1 tells us, outlet temperature of collectors are interrelate with total heat loss of collector U_L, collector efficiency factor F ', unit time quality flow $\dot{m}$, the average temperature of the fluid T_f, environment temperature Ta ,collectors effective lighting area A_C ,solar radiation absorption S radiation and so on. At the same time, S is affected by direct solar radiation ,scattering radiation ,reflection radiation on the ground and installation angle β , the relationship between these parameters are complex, not simple function expression, polysun software was used to simulate solar heating system shown in Fig. 1 for different azimuth, different installation angle and different latitudes.

Fig. 2 shows maximum outlet temperature of collectors T_{fo},that is simulated by polysun at 25°, 45°, 90° installation angle and face South and East respectively. In comparison, the outlet temperature of collectors is highest and minimum in the summer respectively when 45° face east and 90°face south, and between October and November, T_{fo} is highest when β is 90°face south , while there are little difference in others. From Decembers to February, T_{fo} is still the highest when β is 90° face south,followed by 45° face south,β equal to 45° face east and 25° face south is very close .From the simulation,the results are not consistent with the convention recommend increaseing or reducing installation angle 10° than local latitude in winter and in summer.In Lanzhou, ambient temperature is higher and sunlight is strong in summer,so it can meet the requirement for hot water supply.In winter, the outdoor temperature is lower, collectors supply not only hot water but also heating , then, collector installation modes, should as far as possible to meet the requirements in winter.from Fig. 2, 90 ° face south is the best in these types,it is very good for many buildings which will install collectors vertically due to limitation of space. Still further, it has a good building appearance and space saving, will provide a good basis for hot water supply and heating for taking advantage of solar energy in Lanzhou.

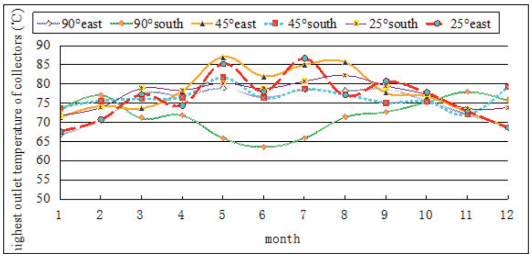

Fig. 2 highest outlet temperature of collectors for six installation ways in Lanzhou

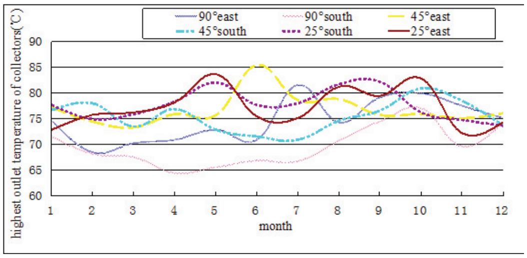

Fig. 3 highest outlet temperature of collectors for six installation ways in Guangzhou

From Fig. 3, T_{fo} is general good while β is 25°face south and worse β is 90°face south in annual. In winter, 25° is the best installation mode for Guangzhou. So there are more difference at different latitude such as Lanzhou and Guangzhou.

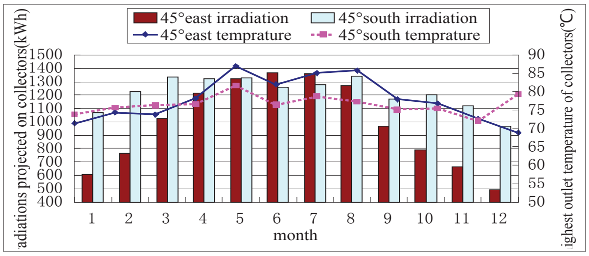

Fig. 4 relationship of collector irradiation and highest outlet temperature of collectors at 45° face east and south in Lanzhou

So, whether solar radiation projected on collectors is more sufficient, outlet temperature of collectors is higher. Fig. 4 and 5 analyzed relationship between outlet temperature and solar radiation while β is 45° and 25° face south and east respectively.solar radiation projected on collectors are much the former than the latter, accordingly,T_{fo} is higher obviously the former than the latter, but there are still some fluctuation. Especially when collectors are installed face east and solar radiation is amount in summer, T_{fo} floats evidently.

In Fig. 6 ,collectors are installed face south and east and β is 90°,irradiation projected on collectors are more sufficient face east than south in summer ,but it is opposite in winter.collectors outlet temperature and radiation have same tendency, without too much turbulence.

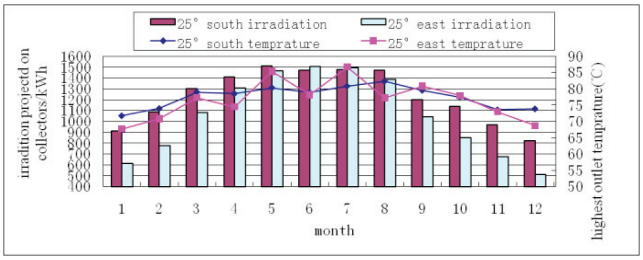

Fig. 5 relationship of collector irradiations and highest outlet temperature of collectors at 25°face east and south in Lanzhou

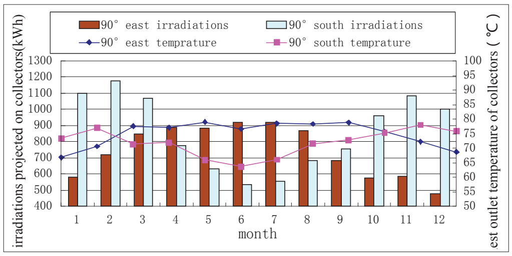

Fig. 6 relationship of collector irradiation and highest outlet temperature of collectors at 90°face east and south in Lanzhou

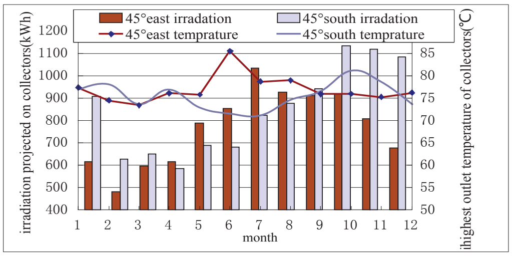

Fig. 7 relationship of collector irradiation and highest outlet temperature of collectors At 45°face east and south in Guangzhou

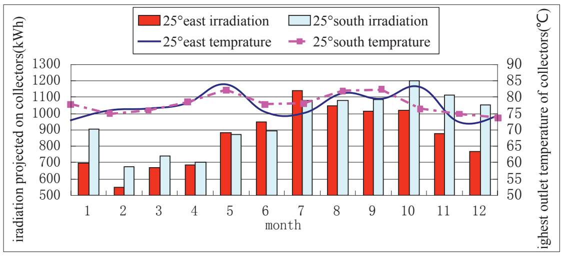

Fig. 8 relationship of collector irradiation and highest outlet temperature of collectors at 25°face east and south in Guangzhou

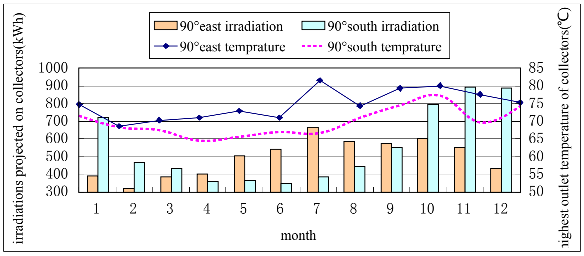

Fig. 9 relationship of collector irradiation and highest outlet temperature of collectors At 90°face east and south in Guangzhou

Fig. 7 indicate relationships of irradiations and highest outlet temperature of collectors, with 45° installation angle and face east and south in Guangzhou, the changes at irradiation and T_{fo} is completely accordance. When β is diminished to 25°(Fig. 8), they are synchronous. When β increase to 90°(Fig. 9), it is unexpected that no matter how irradiation changes, T_{fo} is higher face east than face south.

3. RESULTS

In Lanzhou, T_{fo} is steady and higher when installation angle is 45°face south, it is highest when installation angle is 45° face east in summer, but it is lower than others in winter. In view of use heating in winter, installation angle is 90°and face south is first-rate， because outlet temperature of collectors are highest for 6 modes in winter. Although temperature is lowest in summer, it can reach 40℃ and meet requirement for bath. Even though installation angle and orientation is same， there are huge difference at different latitude， such as Lanzhou and Guangzhou .
In Guangzhou,outlet temperature of collectors is steady and higher at 25°installation angle and face south,irradiation projected on collectors is irregular, not as in Lanzhou, it tell us that performance of collecting system is influenced by many factors and confirmed theory as formulation in equation 1-4.

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