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An Experimental Study on the Characteristic of the Hot Water-Air Heating Generating System with a Solar Collector

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Abstract

A solar air heating has low efficiency compared with the solar water heating because the heat capacity of the air is small. The heat received by solar collector plate is not fully transferred to the air and then a part of them became the losses to the environment through conduction and convection process. This research is focusing on a design of better combined multi-purposed system suggested by us and aims to secure the more efficient solar energy utilization by combining the hot water and air heating system. The result in this paper has shown that the proposed design has better thermal performance than that of the common design. Furthermore, it was found that the performance of the combined air - water heating system increases the efficiency from 30% to 35%-40%.

Keywords : Solar heater, Flat plate solar collector, Air heating, Hot water, Combined solar system

Nomenclatures

A = Cross-sectional area, m^2
A_a = Transparent frontal area, m^2
A_g = Gross collector area, m^2
c_p = Specific heat, J/ (kg.℃)
q_u = Rate of useful energy extraction, W
G_t = Global solar irradiance, W/m^2
F_R = Solar collector heat removal factor, [-]
τ = Transmittance, [-]
α = Absorptance, [-]
U_L = Heat transfer loss coefficient, W/m^2
$t_{f,i}$= Temperature input, ℃
$t_{f,e}$= Temperature output, ℃
t_a = Ambient air temperature, ℃
$\dot{m}$ = Mass flow rate, kg/s

1. Introduction

Solar air heating system is a type of typical solar energy system which collects solar energy and transforms it into thermal energy. The general idea is that while air is flowing through a solar collector, the temperature of air naturally can be heated by strong sun lighting. Circulation of the air in the building can be done by natural driving forces (buoyancy effect) or by fan which is more certain. Optionally the fan can be

powered by solar cell mounted on the roof.

Conventional building heating schemes mainly included boiler heating, heat pump heating and solar energy heating. With the deterioration of energy shortage and environment pollution, solar energy can be used as the substitution of conventional energy for building heating and plays an important role in reducing the dependence on conventional energy resources [1].

Preheating of air supplied to buildings has gained much interests in the recent years. The advantage of this technology is that it is cheap and simple. It can help to get rid of mould and bad smells as well as increase the temperature inside without need of additional heating. In this way the indoor environment in the chamber such as house is maintained on a good level during the winter season.

Solar air heating has low efficiency compared to the solar water heating because the heat capacity of the air is low. The heat received by solar collector plate is not fully transferred to the air, a part of them become losses to the environment through conduction or convection process [2]. This problem becomes a background of this study to design the more efficient solar energy utilization for heating application.

The motivation of this study is to improve the heat gain from the conventional solar air heating system by combining solar air heater with solar water heater. The solar air heating system has low efficiency due to its low thermal capacity.

This goal of the study is to improve the heat gain of the solar heating system. The air heating system has low efficiency because so many losses due to its low thermal capacity, therefore the water heating system is applied together to utilize the losses. This study analyzes the performance of a new design of the solar heating system and also analyzes the effect of the operating temperatures.

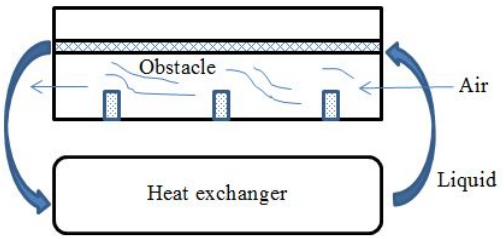

Figure 1. Proposed design of the solar heating system

2. Experimental Method

The ASHRAE 93-2003 standard was used as reference of evaluation in this study. This standard describes test methods for steady-state thermal performance of solar heating system. Fig. 1 shows the design of the proposed collector and Fig. 2 shows the testing configuration for the solar heating system

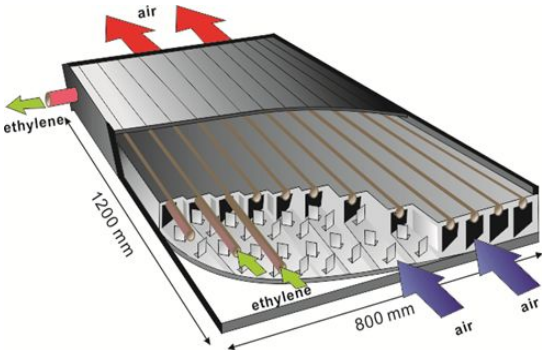

Figure 2. Design of the proposed collector

The thermal performance of a collector can be defined by following equations:

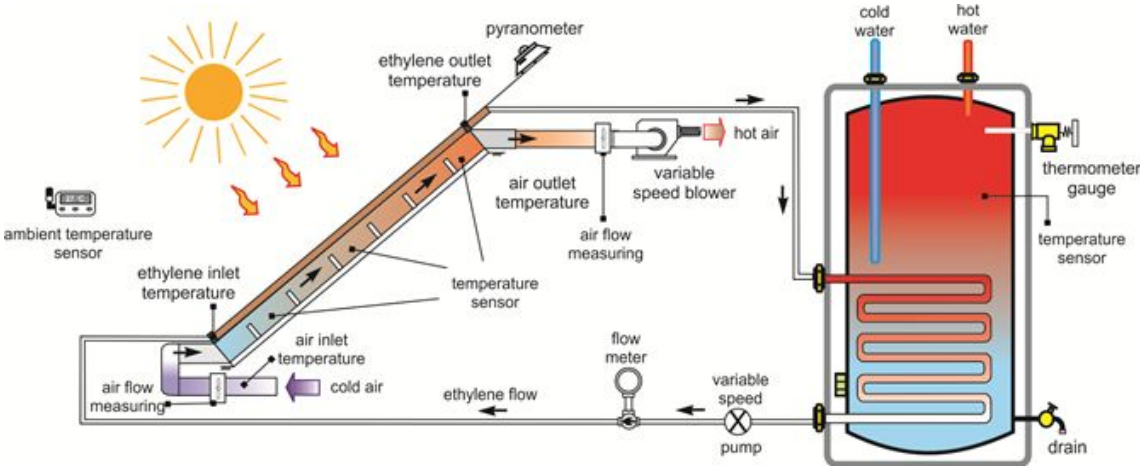

Figure 3. Experimental apparatus for the outdoor

For the liquid heating system,

$$\frac{q_u}{q_a} = G_t F_R(\tau\alpha)_e - F_R U_L(t_{f,i} - t_a) \quad (1)$$

$$q_u = \frac{\dot{m}}{A_a} Cp(t_{f,e} - t_{f,i}) \quad (2)$$

The solar collector efficiency is defined as:

$$n_g = \frac{actual\ useful\ energy}{solar\ energy\ received} \quad (3)$$

Then the efficiency for a non-concentrating collector is given by;

$$\eta_g = (A_a/A_g)F_R[(\tau\alpha)_e - U_L\frac{(t_{f,i} - t_a)}{G_t}] \quad (4)$$

$$\eta_g = \frac{mc_p(t_{f,e} - t_{f,i})}{A_g G_t} \quad (5)$$

For the air heating system,

$$\dot{m}_L = \dot{m}_e - \dot{m}_i \quad (6)$$

$$q_u = \dot{m}_e h_{f,e} - \dot{m}_L h_a \quad (7)$$

$$q_u = \dot{m}_e c_p(t_{f,e} - t_{f,i}) - (\dot{m}_e - \dot{m}_i)c_p(t_{f,i} - t_a) \quad (8)$$

3. Experimental Results

The solar radiation at cold season 10, December 2011 is plotted in Fig. 4. The total efficiency of combined air and water heater system then plotted in Fig. 5. For each comparison, the total efficiency of the air heater system are plotted as shown in Fig. 6.

The Efficiency of single air heater system is around 30%, but after combining with the water heater, the system efficiency increased to around

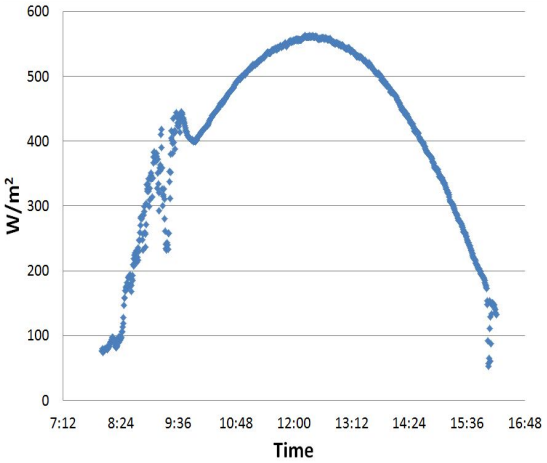

Figure 4. Solar radiation in 10th, Dec 2011

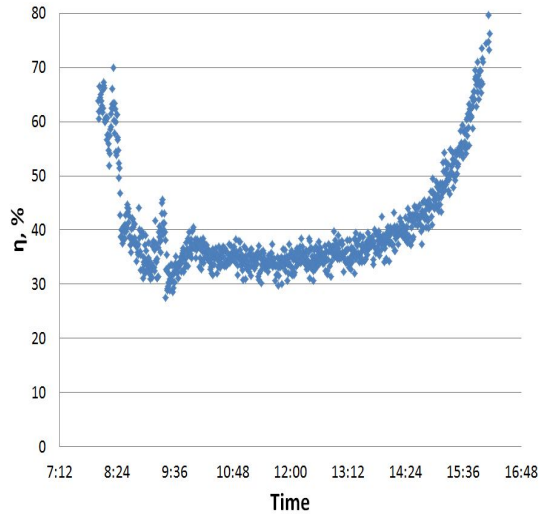

Figure 5. Efficiency of the proposed system

35%-40%. The efficiency increase caused by heat loss of the air heater system is absorbed by the water heating system. Even the water heater system needs pump to activate the system, but still the energy gain is higher the energy for activation.

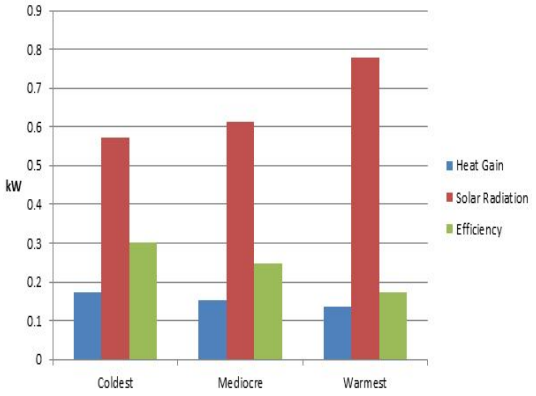

Figure 6. Efficiency of the air heater system

4. Conclusions

This study was done to improve the thermal efficiency from the conventional solar air heating system by making it combined with water heater. The combined air heater with water heater increases the thermal efficiency from 30% up to 40% compared to the conventional type. Even the water heater system needs pump to activate the system, but still the energy gain is still higher the energy activation.

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