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Comparative studies of conical solar collector with and without glass tube

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Abstract

The objectives of this study were to investigate the performance of the given collector with and without glass tube on the absorber pipe with different climatic and operating conditions. Comparative performance evaluation of a conical solar collector for water heating has been performed by using two cases i.e. the absorber pipe covered with and without glass tube. In each case the collector assembly attached with 100 L storage tank, in such a way making closed loop system. Water as a heat transfer fluid was circulated by means of a pump, in order to remove the solar heat from the absorber surface. Difference in efficiency values between both cases of with and without glass tube was significant, and the temperature rise in case of absorber with glass tube was much higher compared to that without glass tube. These results were very encouraging especially for the utilization in high temperature applications. The glass tube on the absorber pipe improved appreciably the thermal performance of the conical solar collector for water heating.

Keywords: concentrator, absorber, thermal efficiency, reflector, storage tank, water heating

INTRODUCTION

There are a lot of policies and interesting about greenhouse gas reduction in the world. Korea is staying in six on amount of greenhouse gas emission according to OECD statistics, total emission in 2006 is 575.4 million metric tons and in 2008 and 2010, its value increases to 604.1 and 668.8 million metric tons respectively. These are continually increasing (Renewable energy, 2015). To solve this problem, Korea government announced to reduce at least 37% greenhouse gas emission until 2030 matching international policies. They are implementing policies such as CCS (Carbon Capture and Storage), improving efficiency of product and device's energy, investment support on facilities saving energy. The amount of solar radiation from the sun is approximately 54 X 10^{24} Joule annually, which is almost 1000 times of the amount of energy used presently in the whole world annually (Ike, 2014).

The clean and emission-free solar energy among other renewable energies indicates high efficiency and rapid growth (Euh et al., 2012; Imtiaz Hussain and Lee, 2014). This solar energy advantage has prompted research and development. Different types of solar collectors have been used by various researchers to harvest the solar energy from the sun. For example, passive solar or active solar technologies depending on the way they use, passive solar technologies tube a building orienting to the sun, selecting materials with favorable thermal mass. Active solar technologies include the use of pump to circulate the thermal fluid through the collector to get energy (Suhas et al., 2015). It can be found that the heat loss becomes smaller by concentrating radiation (Zhai et al., 2010).

In addition, numerous solar collector studies have been conducted by scientists to apply solar energy to daily life and industries, such as comparison of flat-plate type with coning type, air heater using conical solar collector, finding of optimum temperature, the development of conical solar concentrator, applications of solar thermal collectors, and conical solar collector by using nano-fluids etc (Togrul et al., 2004; Bancha and Somchai, 2005; Kurtbas and Durmus,

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2007; Vijayan et al., 2013). But, comparative study on collector thermal performance with and without glass tube is rarely presented. In this study, solar collecting efficiency and optimum flow rate were investigated on conical solar collector with and without glass tube.

MATERIALS AND METHODS

The conical shaped solar collector to reflect the sun-light was made of using the stainless steel material. It concentrates the incident solar radiation on to the whole absorber surface with concentration ratio of 13X. Detail diagram of conical reflector including all dimensions is shown in figure 1.

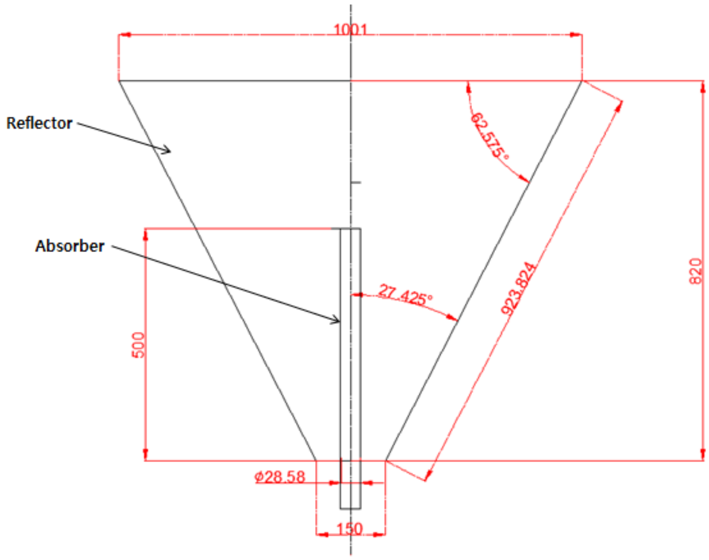

Figure 1. Drawing of conical solar collector.

Comparative study has been performed by varying the volumetric flow rates of water and the absorber type. In the first case, the CTA(Concentric Tube Absorber) was constructed by combining different diameter pipes made of copper and the outer surface was painted with black color to increase absorption of radiation. Water is circulating into absorber pipe from inlet A to outlet B as shown in figure 2. The whole absorber length is 810 mm with both pipes outer diameters are 15.88 mm and 28.58 mm, respectively. In the second case, the same CTA was used, but with the addition of the glass tube as shown in figure 3. Installation of glass tube reduces the amount of heat loss from the absorber outer surface. The water flows through CTA with glass tube from inlet A to outlet B in figure 3.

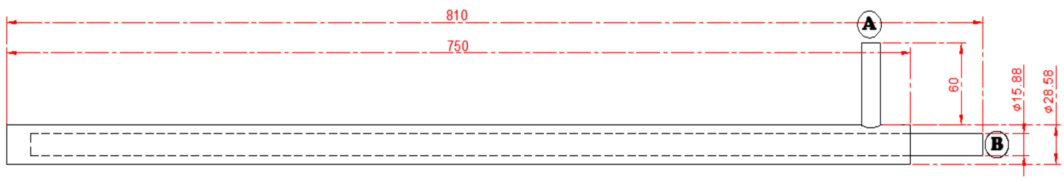

Figure 2. Drawing of CTA.

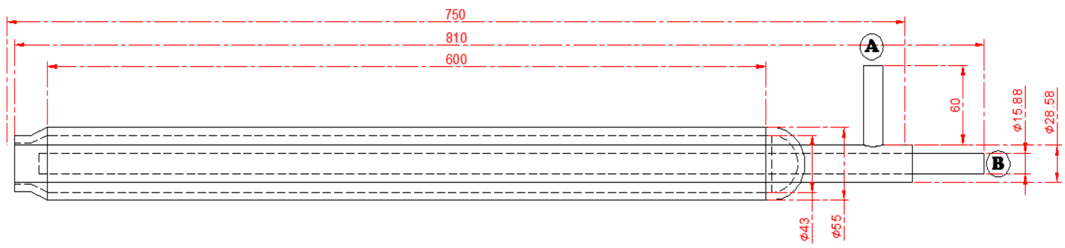

Figure 3. Drawing of CTA with glass tube.

For water storage, a storage tank of 80L was used which is highly insulated with glass fiber insulation. 3 resistance temperature detectors was used such as at the top, meddle and bottom of the storage tank, respectively, to measure the temperature of water correctly.

In the first case, experimental measurements were performed from October 10 to 20, 2015 at Kangwon National University, South Korea (36° 18' N, 126° 24' E, and 100m height above sea level). These experiments were performed using CTA with different volumetric flow rates of 3, 4, 5 and 6 L/min. The operating conditions for the experiments during the daylight of the given period are provided in table 1.

Table 1. The environmental conditions of the experiment with CTA.

Flow rate	Inlet temperature (°C)	Direct solar radiation (W/m^2) Min/Max	Ambient temperature (°C)	Air velocity (m/s) Min/Max
3 L/min	30~41	715/854	22~27	0.5/3.2
4 L/min	30~43	752/840	25~31	0.2/0.8
5 L/min	33~42	702/812	15~17	0.01/0.06
6 L /min	32~41	721/829	19~28	0.1/1.2

Second experimental measurements were performed from November 10 to 30, 2015 at the same place as the first case. The operating conditions for these experiments during the given period are provided in table 2.

Table 2. The environmental conditions of the experiment with CTA with glass tube.

Flow rate	Inlet temperature (°C)	Direct solar radiation (W/m^2) Min/Max	Ambient temperature (°C)	Air velocity (m/s) Min/Max
3 L/min	24~35	725/814	7~10	0.3/1.4
4 L/min	30~42	752/821	9~13	0.2/1.2
5 L/min	25~34	601/741	5~7	1.4/3.6
6 L /min	26~35	714/809	7~10	0.2/1.9

The experimental setup with configurations of conical solar collector and the photograph of conical solar collector are presented in figure. 4.

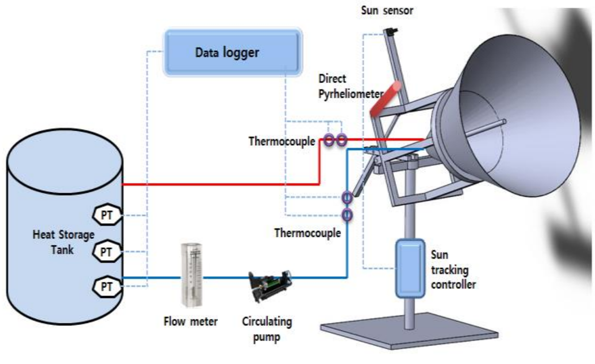

Figure 4. Configuration and photograph of conical solar collector.

RESULTS AND DISCUSSION

Table 3 shows different values of solar collecting efficiency according to volumetric flow rate. It can be observed that the average solar collecting efficiency measured for 4 L/min is higher value as compared with other volumetric flow rate as 65.2% and solar collecting efficiency calculated for 3L/min, 5L/min and 6L/min are 62.8%, 57%, and 52.7% respectively in CTA. In the case of glass tube, the optimum flow rate was found at 5 L /min as 69.8%. Solar collecting efficiency for other flow rates of 3, 4, and 6 L/min are 51.1%, 56.8%, and 58.1% respectively. The heat transfer coefficients between the absorber pipe and the flowing fluid and the solar collecting efficiencies at different flow rates are presented in table 3, for both cases. Figure 5 shows the comparison of efficiency with and without glass tube.

Table 3. The efficiency and total heat transfer coefficient according to the absorber type.

Efficiency / Flow rate	Collecting efficiency of CTA (%)	Collecting efficiency of CTA with glass tube (%)	Heat transfer coefficient of CTA ($W/m^2 °C$)	Heat transfer coefficient of CTA with glass tube ($W/m^2 °C$)
3 L/min	62.8	51.1	40.4	18.6
4 L/min	65.2	56.8	64.1	20.8
5 L/min	57.0	69.8	24.7	22.4
6 L /min	52.7	58.1	22.6	19.9

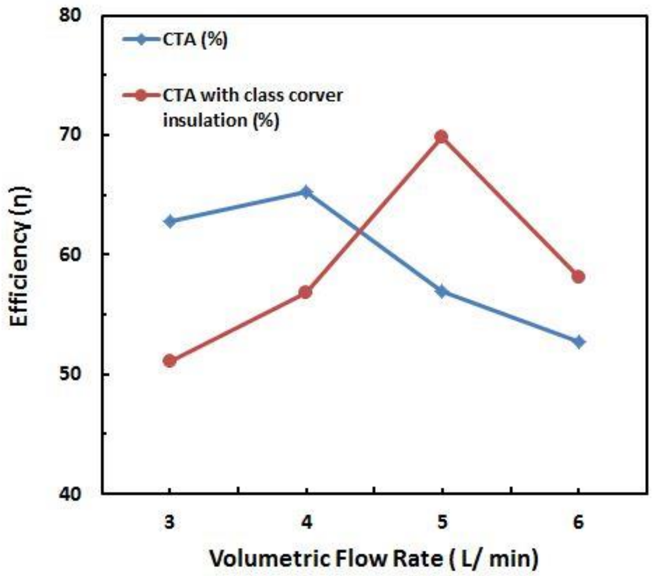

Figure 5. Comparison of efficiency with and without glass tube.

CONCLUSIONS

The following conclusions can be drawn from the study:

– The experimental study on the conical solar collector with and without glass tube was conducted to find solar collecting efficiency and optimum flow rates. The efficiency of the conical solar collector varies in function of solar radiation, flow rate, ambient temperature, wind velocity, inlet and outlet temperatures etc.

– The experimental results indicate that an optimal flow rate with the maximum efficiency of 65.2% was 4L/min due to the highest convection heat transfer coefficient between absorber and water. In the case of absorber with glass tube, the maximum efficiency of 69.8% was found at an optimal flow rate of 5L/min. it can be explained that at low flow rate, the heat loss is high due to higher temperature of heating medium and the absorber pipe.

– In addition, at very high flow rate, the circulating fluid cannot remove all of the solar heat from the absorber surface. Thus, the collector efficiency with glass tube is found to be 4.6% higher than the CTA without glass tube because the heat losses are lowered with glass tube.

ACKNOWLEDGEMENTS

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Literature cited

Euh, S. H., Lee J. B., Choi Y. S., and Kim D. H., (2012). The performance and efficiency analysis of PVT system: A Review. J. Korean Sol. Energy Soc. *32(2),* 1-10

Ike, C. U. (2014). Development and construction of a conical solar concentrator. Int. J. Basic & Appl. Sci. *3(4),* 490-496

Imtiaz Hussain, M., and Lee G. H. (2014). Thermal performance evaluation of a conical solar water heater integrated with a thermal storage system. Energy Convers. Manage. *87*, 267-273

Kongtragool, B., and Wongwises S. (2005). Optimum absorber temperature of a once-reflecting full conical solar collector of a low temperature differential stirling engine. RE. *30(11).* 1671-1687

Kurtbas, I. and Durmus A. (2007). An comparison of a new type conical solar collector with a flat-plate solar collector. e-Journal of New Word Sciences Academy. *2(2),* 163-172

Renewableenergy. (2015). https://www.renewableenergy.or.kr/main.do

Suhas, V., Sukeerth Calastawad, Sawan Kumar S., Purujeeth, and Shyam sharma, R. (2015). Performance of a conical shaped solar water heater with that of a conventional solar water heater. Int. Res. J. Eng. Technol. *2(4),* 800-803

Togrul, I. T., Pehlıvan and D., Akosman C., (2004). Development and testing of a solar air-heater with conical solar collector. RE. *29 (2),* 263-275

Vijayan, G., Vinu Sevastian M., Umarani K., and Dr. Karunakaran R. (2013). Design, fabrication and performance study of frusto-conical solar collector by using nanofluids. Int. J. Eng. Res. Technol. *2(5),* 1220-1226

Zhai, H., Dai Y. J., Wu J. Y., Wang R. Z., and Zhang L. Y. (2010). Experimental investigation and analysis on a concentrating solar collector using linear Fresnel lens. Energ. Convers. Manage. *51 (1),* 48-55