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MEASUREMENT CHAIN FOR THE BIFACIAL AND THE CONVENTIONAL FLAT-PLATE WATER SOLAR COLLECTORS

Abstract: *The term bifacial flat-plate water solar collector means a solar collector that can absorb solar irradiation by its upper as well as its lower absorber surface. Absorption of solar radiation by its lower absorber surface is achieved by using reflective surface (reflector) placed below the collector. Compared to a conventional flat-plate water solar collector, the analyzed collector insulation, placed in the bottom of the box, is replaced by glass cover (glazing). In this paper a measurement chain for testing the mentioned specific solar collector and the conventional collector is presented. The measurement chain would provide data about instantaneous useful energy gain and efficiency for both collectors.*

Keywords: *bifacial flat - plate water solar collector, experiment, measurement*

1. INTRODUCTION

A bifacial flat-plate solar collector (BFPC) is a solar collector which can absorb solar irradiation simultaneously from both its upper and lower absorber surfaces (LAS). Absorption of irradiation from the LAS is accomplished using a flat-plate reflecting surface (reflector) placed below the collector. To enable absorption from the LAS it is necessary beside the reflector that insulation in lower part of the collector box be replaced with glazing. In this paper the measurement chain with measuring equipment for the experimental testing of the BFPC and the conventional collector (FPC) is presented. The measurement chain would provide data about instantaneous useful energy gain and efficiency for both analyzed collectors.

2. EXPERIMENTAL SETUP OF THE BFPC AND FPC COLLECTORS

The main objectives of the experimental study are to investigate the feasibility of the proposed concept, the comparison of the experimental and theoretical results as well as the verification of the theoretical models. In this chapter the experimental setup of the BFPC and FPC collectors is presented.

The experimental setup of the tested collectors is installed in the open area of the Thermodynamics and Thermotechnics Laboratory of the Faculty of Engineering Kragujevac. The setup includes: the collector - reflector system (CRS), the FPC and the hydraulic installation.

The CRS consists of the supporting construction (Figure 1, position 1), the BFPC (Figure 1, position 2), the reflector (Figure 1, position 3) and the construction for reflector movement (Figure 1, position 4).

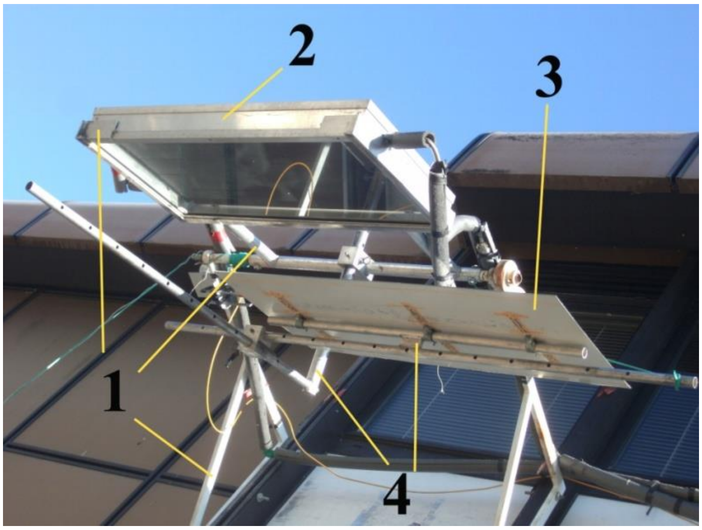

Figure 1. The collector-reflector system: 1-supporting construction, 2-BFPC, 3-reflector and 4- construction for reflector movement

The supporting construction of the CRS includes two cantilevered brackets (Figure 2 (left), position 1), the axle with dividing head (Figure 2 (left), position 2) and the collector bracket (Figure 2 (left), position 3). The connection between the vertical wall of the Laboratory and the CRS is accomplished by two steel cantilevered brackets. The aluminum collector bracket (Figure 2 (left and right)) beside carrying weight of the collector carries weight of the construction for the reflector movement as well as weight of the reflector. During its design it is taken into account that profiles of its sides do not cover the area of the glazing.

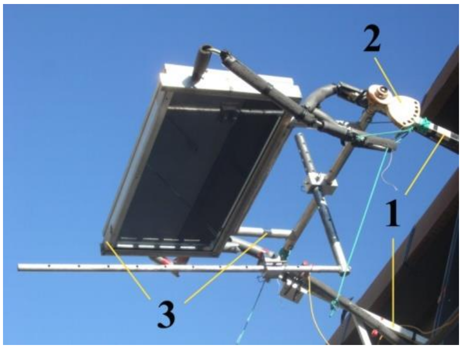

Figure 2. The supporting construction of the CRS (left) : 1-cantilevered bracket, 2-axle with dividing head and 3-collector bracket, and the collector bracket (right)

The chosen reflector presents plexiglass mirror with dimensions of 1000 x 500 x 2 mm. The reflector is always placed in parallel with the collector.

Because the sun changes its position on the sky during the day and year it is necessary to move the reflector in order to LAS be partially or preferably completly irradiated. The reflector is moved manually in three orthogonal directions, direction normal to its plane, direction normal to its lenght and direction normal to its width. In order to do that the aluminum construction for its movement is designed (Figure 3 (left)). It consists of the rectangular frame (Figure. 3 (left), position 1) and the reflector frame (Figure 3 (left), position 2). By the vertical part of the rectangular frame the distance between the reflector and collector changes in direction normal to their planes. Moving of the reflector across the horizontal part of this frame the distance between the reflector and collector axis changes but in direction normal to their lenght. The axial distance between holes on the vertical part of the frame is 50 mm, while the same distance on the horizontal part is 100 mm. In order to move the reflector in direction normal to its width the frame on which the reflector is attached was designed. The axial distance between holes on this frame is 100 mm. The fixing of the reflector in certain position is accomplished using the aluminum cubes and wedges.

The FPC, presented on Figure 4 (left), has dimensions 940 x 476 x 80 mm. Its housing, absorber and all tubes are made from same material as the ones for the BFPC. Below the absorber, in the lower collector box, the insulation as hard - pressed wool of width of 40 mm is placed.

Figure 4. The FPC (left) and the both analyzed collectors (right)

The supporting construction of the FPS is similar to the one for the BFPC. On the Figure 4 (right) the both analyzed collectors mounted on the south-west wall of the Laboratory are presented.

The third component of the experimental setup presents the hydraulic installation. On the Figure 5 the schema of the hydraulic instalation with its loops and components is presented. The working fluid in the hydraulic instalation is water from the water supply system. Before entering the solar collectors, the water passes through the boiler with electric heater (Figure 5, position 3). The boiler heats the water to the value of the water inlet temperature in the solar collectors. After leaving the boiler the water is directed to the solar collectors. From the boiler two streams start: the first one inludes the BFPC (Figure 5, position 1) and the second one inludes the FPC (Figure 5, position 2). The mass flow rate of the water is regulated by using the regulating valves (Figure 5, position 4). The position 6 on the Figure 5 presents the volumetric tank. There are two tanks one for the BFPC and second for the FPC. They are used for the measuring of the mass flow rate of the water. The hydraulic installation does not inludes the circulating pump. This is because the mass flow rates of the water are very small as a consequence of relatively small absorber areas. The necessary pressure in the installation is provided by connecting the hydraulic installation with the water supply system.

3. MEASUREMENT CHAIN AND MEASURING EQUIPMENT

The experimental results give information about the thermal behavior of the tested collectors. The thermal behavior of the collectors describe the parameters as useful energy gain and the thermal efficiency. In order to calculate them the parameters as the mass flow rate of the water for the BFPC (FPC) (m_c (m_d)), the inlet water temperature for the BFPC (FPC) ($T_{c,i}$ ($T_{d,i}$)), the outlet water temperature for the BFPC (FPC) ($T_{c,o}$ ($T_{d,o}$)), the intensity of the solar radiation on the horizontal surface (H'), the ambient temperature (T_a) as well as the wind velocity have to be measured. Figure 5 presents the schematic view of the experimental setup with the measurement chain.

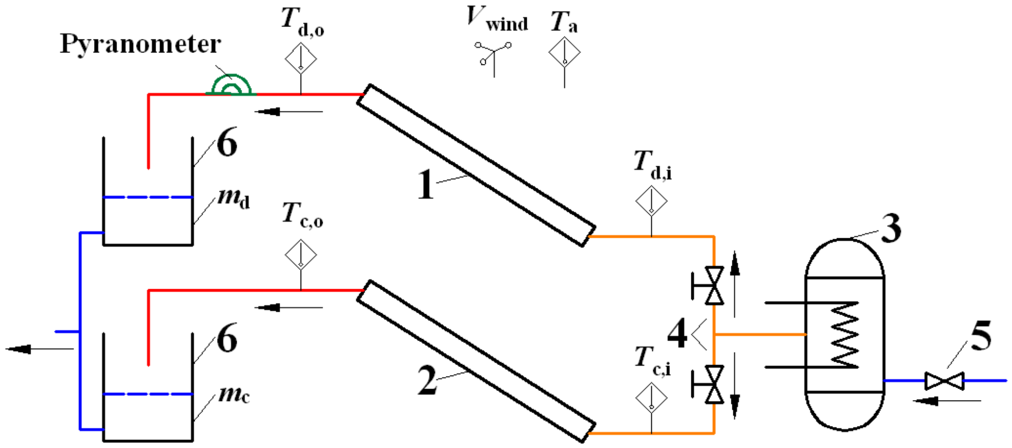

***Figure 5.** Schematic view of the experimental setup with the measurement chain: 1 - BFPC, 2 - FPC, 3 - boiler with electric heater, 4 - regulating valve, 5 - valve on/off, 6 - volumetric tank*

The mass flow rate of the water is measured in the simplest and most reliable way using the volumetric tank (Figure 6) and the stopwatch.Before measuring, the tanks are scaled using the laboratory measuring cylinders. The distance between two scale lines presents volume of 5 l. At the beginning of each measurement the initial volume of the water in the tank and the time in that moment are recorded. When the tank become full of water (50 l) the stopwatch is used again to read the time which passed between the state when the tank was empty and the state when the tank became full of water. After reading this time the mass flow rate of the water for that time period can be calculated. In order to measure the mass flow rate for the next time periods the tanks are completely discharged by connecting them with the sewage system with a rubber hose. The mass flow rate of the water is controlled using the regulating valve (Figure 7 (left)).

Figure 6. View of the volumetric tanks and positions of the electric thermometers for the BFPC (left) and the FPC (right): 1 - Pt-100 resistance thermometer at the inlet of the solar collector and 2 - Pt-100 resistance thermometer at the outlet of the solar collector

The measurement of the solar radiation on the horizontal surface is conducted using Kipp & Zonen pyranometer (Figure 7 (right)).

The pyranometer mounted on the cantilevered bracket of the CRS is set in a horizontal position using its own adjusters.

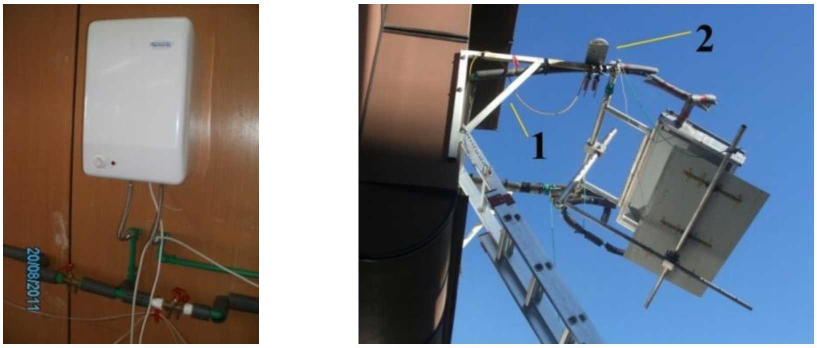

Figure 7. View of the boiler with the regulating valves (left) and the position of the mounted pyranometer (1 - cantilevered bracket of the CRS, 2 - pyranometer) (right)

The electrical resistance thermometers with Pt - 100 sensors are used for the measurements of the inlet and outlet water temperatures from the collectors. The value of the inlet water temperatures is manually adjusted using the potentiometer of the boiler. The power and volume of the boiler are 2 kW and 10 l, respectively (Fig. 7 (left)). The position of the thermometers in the experimental setup is shown in Fig. 6. All thermometers are connected with the data acquisition system (Figure 8 (right)) through the transmitters (Figure 8 (left)). In this way the automatic collection and recording of the data is provided.

Figure 8. View of the the chosen transmitters (left) and the data acquisition system (right)

The dry bulb thermometer, mounted on the window of the Laboratory and protected from the sun and wind, is used for the measuring of the ambient temperature. The wind velocity is not experimentally measured. The data about this parameter are obtained from the meteorological station in Kragujevac.

4. CONCLUSION

In this paper the experimental setup of the bifacial and the conventional solar collectors is described. The installation is made in order to obtain data about the thermal behaviour of these two collectors, their useful energy gain and the thermal efficiency. For the verification of the proposed mathematical models of the performance of these solar collectors the experimental data will be compared with the data obtained using mentioned models. The experimental data are collected and recorded using the measurement chain with the measuring equipment described in this paper, too.

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