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RESULTS OF THE EXPERIMENTAL VERIFICATION OF THE MATHEMATICAL MODEL OF THE THERMAL BEHAVIOUR OF A DOUBLE EXPOSURE FLAT-PLATE SOLAR COLLECTOR

Abstract: *The double exposure flat-plate solar collector (DEFPC) is a solar collector which can absorb solar radiation by upper as well as lower absorber surface. Absorption from lower absorber surface is enabled by application of a flat-plate reflector. The reflector is placed in parallel below the collector. To enable absorption from the lower absorber surface, it is necessary, beside the reflector, for the insulation mounted on the lower part of the collector box to be removed and the lower box surface replaced by a glass cover. In this paper the results of the experimental verification of the mathematical model of the thermal behaviour of a DEFPC are presented. The experiments were performed in the months of August, September and October of 2012.Theoretical and experimental results of the thermal power of the analyzed DEFPC for the five selected dates are presented. The mean daily deviations of the theoretical results range from 3.43% to 7.23%.*
Keywords: *Solar collector, Reflector, Experiment*

1. INTRODUCTION

A double exposure flat-plate solar collector (DEFPC) is a solar collector which can absorb solar radiation 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 in parallel below the collector. On the other side, absorption from the upper absorber surface is the same as that in the conventional flat-plate solar collector (FPC). To enable absorption from the lower absorber surface, it is necessary for the insulation mounted in the lower part of the collector box to be removed and the lower box surface replaced by glass cover. In relation to the previously investigated systems [1-4], the analyzed collector-reflector system (CRS) is different for many reasons. The first reason is parallelism between the collector and reflector. In this way, the incident angle of the solar beam falling on the upper absorber surface is the same as the incident angle of the solar beam reflected onto the LAS. The second reason relates to the fact that the used reflective surface in this system is a plexiglass mirror. With the mirror surface the reflection is specular, which means that the incident and reflected angles are the same. The reflector is movable in all three possible orthogonal directions: north-south, east-west and normal to its surface. Reflector dimensions are approximately the same as dimensions of the collector. In order to define the optimum position of the reflector relative to the collector, theoretical investigation and verification of the mathematical model for determining the irradiated area of the LAS of the DEFPC were carried out [5]. At the same time with testing the DEFPC, the flat-plate solar collector (FPC) with single glazing and identical absorber characteristics was also tested in order to define the differences in their performance. This paper relates to the results of the experimental verification of the mathematical model of the thermal behaviour of a DEFPC.

2. EXPERIMENT

The experimental installation of the tested solar collectors is located in the Laboratory for Thermodynamics and Thermotechnics at the

Faculty of Engineering Kragujevac. The installation includes collector-reflector system, conventional solar collector, hydraulic and measuring installation. The collector-reflector system (Figure 1) consists of the support construction (position 1), the DEFPC (position 2), the reflector (position 3) and the construction for the reflector movement (position 4).

Technical characteristics of the analyzed DEFPC are given in Table 1.

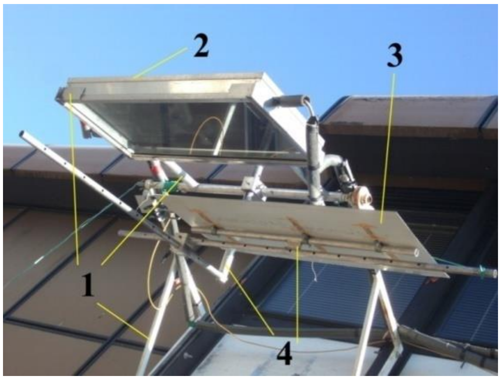

Figure 1- *The collector-reflector system: 1 - support construction, 2 - DEFPC, 3 - reflector and 4 - construction for the reflector movement*

Table 1. *Technical characteristics of the tested DEFPC*

Reflector lenght (m)	1
Reflector width (m)	0.5
Coefficient of reflection (Plexiglass mirror) (-)	0.9
Absorber lenght (m)	0.840
Absorber width (m)	0.460
Absorber thickness (m)	0.002
Absorber emittance (-) (Aluminum)	0.9
Absorber absorptance (-) (Aluminum)	0.9
Distance between absorber tubes (m)	0.092
Inside diameter of the absorber tube (m) (Copper)	0.015

Experimental testing of the DEFPC was performed for different values of the volume flow rate and the water inlet temperature from 5th of August to 19th of October 2012. Since the experimental installation is open air and the used working fluid was water, the DEFPC was tested only when the lowest ambient temperature was above zero. Measurements of a thermal performance of the DEFPC started at 10:00 am and finished at 5:00 pm. During the testing period, which included the end of September and beginning of October, the measurements would be finished before 5:00 pm because of the presence of the shadow from neighboring objects on the CRS.

In the mentioned testing period the DEFPC was inclined at the angle of G = 36° and oriented at the angle of α = 147° which was partly defined by the position of the object at which the CRS was mounted. The reflector of the CRS was moved manually every hour during the testing period in relation to its optimal position in the middle of a one-hour testing period. Every testing day data about the instantaneous horizontal solar radiation, the water inlet and outlet temperatures, the mass flow rates, the ambient temperature and the wind speed were recorded simultaneously.

3. RESULTS

In this paper the results of the experimental verification of the mathematical model of the thermal behaviour of a DEFPC are presented. The experiments were performed in the months of August, September and October of 2012.Theoretical and experimental results of the thermal power of the analyzed DEFPC ($Q_{d,t}$, $Q_{d,e}$) for the five selected dates, 8th and 20th of

August, 4th and 9th of September and 4th of October, are presented. The mathematical model of the thermal behaviour of the DEFPC is explained in detail in [6].

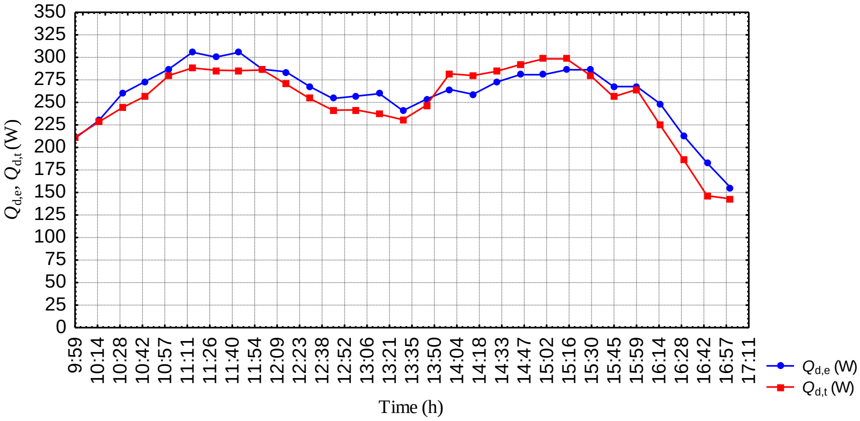

Figure 2 *- Theoretical and experimental thermal power of the DEFPC ($Q_{d,t}$, $Q_{d,e}$) for the 8th of August 2012*

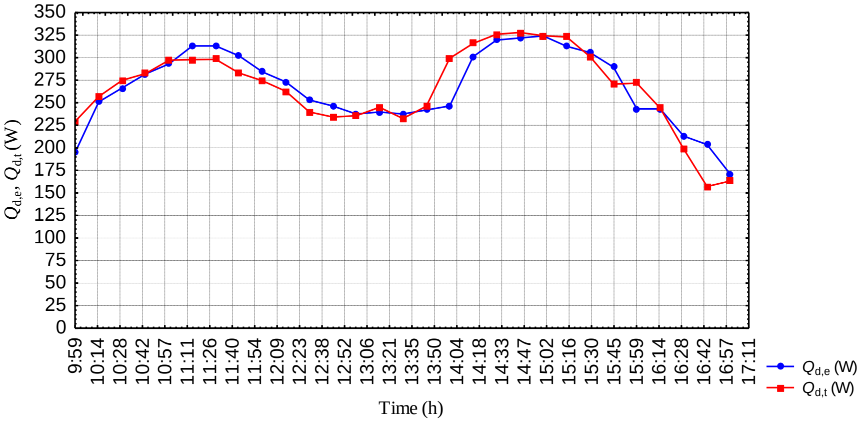

Figure 3 *- Theoretical and experimental thermal power of the DEFPC ($Q_{d,t}$, $Q_{d,e}$) for the 20th of August 2012*

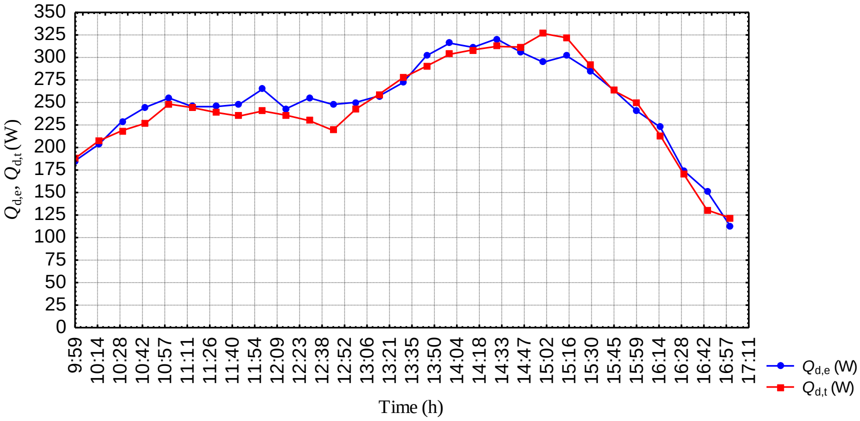

Figure 4 *- Theoretical and experimental thermal power of the DEFPC ($Q_{d,t}$, $Q_{d,e}$) for the 4th of September 2012*

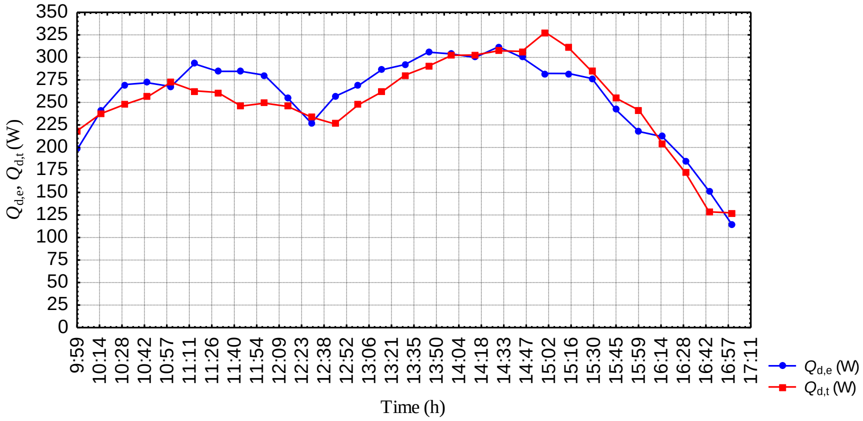

Figure 5 *- Theoretical and experimental thermal power of the DEFPC ($Q_{d,t}$, $Q_{d,e}$) for the 9th of September 2012*

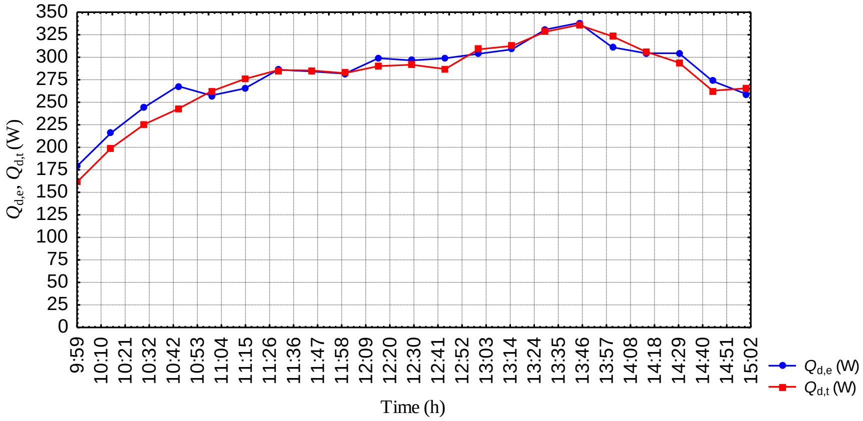

Figure 6 *- Theoretical and experimental thermal power of the DEFPC ($Q_{d,t}$, $Q_{d,e}$) for the 4th of October 2012*

The minimum and maximum deviations of the theoretical thermal power of the DEFPC $Q_{d,t}$ from the experimental $Q_{d,e}$ are: 0.27-24.92% (8th of August), 0.03-29.62% (20th of August), 0.31-15.97% (4th of September), 0.51-17.84% (9th of September) and 0.1-10.83% (4th of October). The mean daily deviations for the analyzed dates are: 5.93% (8th of August), 5.30% (20th of August), 4.68% (4th of September), 7.23% (9th of September) and 3.43% (4th of October).

The highest deviations occur in the last testing hour due to the transient effect. The transient effect is a consequence of the higher temperature of the DEFPC system and its slightly higher heat capacity, in relation to the FPC system.

Also, for the period around noon the values for the $Q_{d,e}$ were slightly higher than the values for the $Q_{d,t}$. The reason is the influence of the reflected reflected radiation from the absorber and glass, the reflected heat losses from the absorber and the transient effect. For this testing period the incident angle of the solar beam was very low and because of that the reflector was underlined below the DEFPC.

Beside the previously mentioned effects, the deviation of the $Q_{d,t}$ from the $Q_{d,e}$ was affected by as follows: the dust of the atmosphere, the occurrence of dust on the collector glazing, the small changes in flow rates and wind speed, unideal reflection of the solar radiation from the reflector and unideal parallelism of the reflector in relation to the collector. Theoretically it is very complicated to define how and in what amount the mentioned influencing factors affecting the value of the thermal power of the DEFPC. Since the values of the calculated deviation of the theoretical and experimental useful thermal power of the DEFPC are relatively small it was concluded that the mathematical model of the thermal behaviour of the DEFPC is experimentally confirmed.

4. CONCLUSIONS

This paper relates to the results of the experimental verification of the mathematical model of the thermal behaviour of the DEFPC. The verification was conducted for five selected dates: 8th of August, 20th of August, 4th of September, 9th of September and 4th of October. The mean daily deviations of the values of the theoretical thermal power of the DEFPC from the experimental amount: 5.93% (8th of August), 5.30% (20th of August), 4.68% (4th of September), 7.23% (9th of September) and 3.43% (4th of October). Since the mentioned deviations are relatively small it was concluded that the mathematical model of the thermal behaviour of the DEFPC is experimentally confirmed.

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