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MEAN FLUID TEMPERATURE OF THE DOUBLE EXPOSURE AND THE CONVENTIONAL FLAT-PLATE WATER SOLAR COLLECTORS - EXPERIMENTAL RESULTS

Abstract: *In this paper the results of the experimental testing of the double exposure flat-plate (DFPC) and the conventional flat-plate (FPC) water solar collectors are presented. The results are related to the mean fluid temperatures of these two solar collectors. The DFPC is a solar collector which can absorb solar irradiation by upper as well as lower absorber surface (LAS). Absorption from lower surface is enabled by application of a flat-plate reflector. The reflector is placed below and in parallel with the collector. In this paper the experimental resuts for 20 August, 04 September and 04 October of 2012 are presented. The maximum absolute difference between temperatures* $T_{d,fm}$ *(DFPC) and* $T_{k,fm}$ *(FPC) was in the morning (2.17°C) and afternoon (1.87°C), in the periods of the maximum achieved irradiation of the LAS.*
Keywords: *solar collector, 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 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 removed and the lower surface of the collector box replaced with glazing. On the other side, absorption from the upper absorber surface is the same as that in the conventional flat-plate solar collector (FPC). In this paper experimental results of the testing of the DFPC and FPC are presented. The results are related to the values of their mean fluid temperatures $T_{k,fm}$ (FPC) and $T_{d,fm}$ (DFPC).

2. EXPERIMENT

On the Figure 1 the experimental installations of the tested solar collectors are presented. Both installations are located in the Laboratory of Thermodynamics and Thermotechnics of the Faculty of Engineering Kragujevac. The DEFPC and FPC were tested for different water mass flow rates and different values of the water inlet temperature from 05 August to 19 October of 2012. The water from the water supply system was used as a working fluid. Daily tests of the solar collectors were often started at 10 a.m. and finished at 5 p.m..

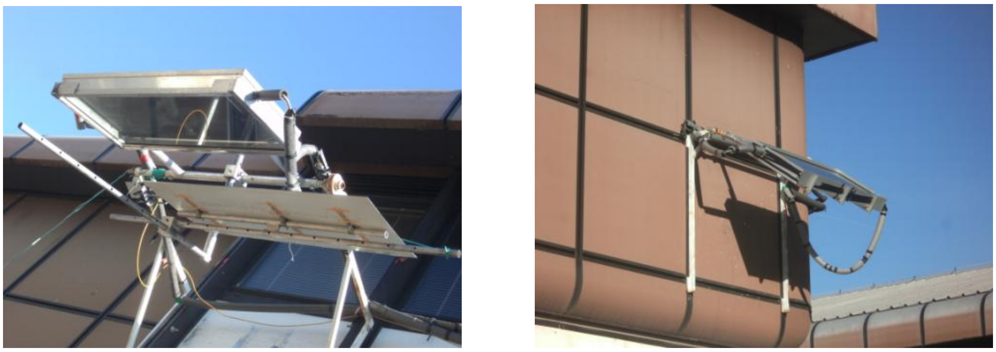

Figure - Experimental installation of the double exposure (left) and conventional solar collector (right)

During the period which incuded the end of September and beginning of October the tests were finished even before 5 p.m. because of the presence of shadow of the neighboring objects on the collector-reflector system. Both solar systems were set up at the tilt angle G = 36° and orientation α = 147°. This tilt angle was chosen because this is the angle which is approximetely the same as the yearly optimum tilt angle of the solar collector for Kragujevac of 37.5° [1]. According to the [1] the yearly optimum orientation of the solar collector for Kragujevac is 180°. The tested solar collectors could not be set to that orientation because of the problems related to the mounting of the outdoor installation and the fact that the south-west wall of the Laboratory was the only location where it was possible to mount the solar collectors. However, the basic idea of testing of solar collectors implied identical conditions for FPC and DFPC. The reflector was moved manually every hour during the testing. For every dayly test tha data about the instantaneous global horizontal radiation, the ambient temperature, the inlet and outlet water temperatures and the mass flow rates of the solar collectors were collected simultaneously. The conditions and procedure of the testing as well as the detail description of the experimental installations can be found in [2].

3. RESULTS

Experimental tests of both solar collectors were carried out during August, September and October 2012. In this paper the experimental results and diagrams of the mean fluid temperatures $T_{k,fm}$ and $T_{d,fm}$, the ambient temperature T_o and irradiation area of the LAS (A_{ozr}) for 20 August, 04 September and 04 October of 2012 are presented as a function of time (Fig. 2-4). The mean fluid temperatures were derived as arithmetic mean of inlet and outlet fluid temperature

From the above diagrams it can be noticed that the shape of the curve of the mean fluid temperature of the DFPC corresponds to the shape of the curve of the irradiation area of the LAS. For all analyzed days the value of $T_{d,fm}$ is higher than the value of $T_{k,fm}$. This is a consequence of a higher amount of absorber radiation and useful heat power of the DFPC in relation to the FPC. The highest absolute difference between temperatures $T_{d,fm}$ and $T_{k,fm}$ was in a period when the values of the percentage difference of the total absorber radiation (ΔI) and heat power (ΔQ) of these solar collectors were highest. In this case, these periods are related to the morning and afternoon. The average value of irradiation area A_{ozr} and percentage difference ΔQ for mentioned periods as well as entire day are given in Table 1

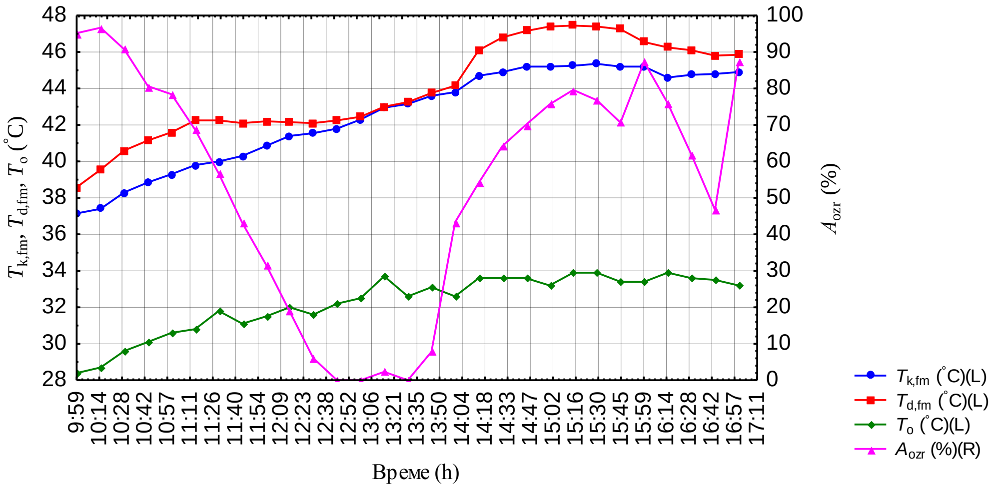

Figure 2 - Experimental diagrams of temperatures $T_{k,fm}$, $T_{d,fm}$, T_o and irradiation area A_{ozr} as a function of time for 20 August 2012.

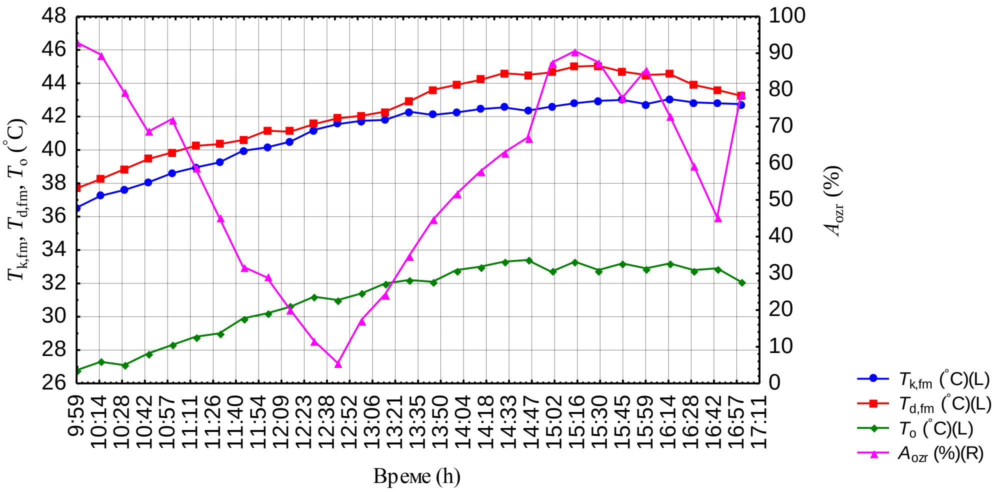

Figure 3 - Experimental diagrams of temperatures $T_{k,fm}$, $T_{d,fm}$, T_o and irradiation area A_{ozr} as a function of time for 04 September 2012.

The values of difference between $T_{d,fm}$ and $T_{k,fm}$ in the morning are: 2.17˚C (20.08.), 1.21˚C (04.09.) and 1.34˚C (04.10.), and in the afternoon: 1.64˚C (20.08.), 1.52˚C (04.09.) and 1.87˚C (04.10.). The lowest difference between these temperatures, for all days except for 04.10., was around noon. In that period the irradiation of the LAS and thus the value of the ΔI and ΔQ were lowest during the entire day. At that time the values of $T_{d,fm}$ were approximate to the vales of $T_{k,fm}$. On 04.10., around noon, the average irradiation of the LAS was around 66 % while for other days it had a value in a range of 12-24 %. Also, the value of the dayly average irradiation of the LAS for this day is 76.17 %. Therefore, there is a uniformity of difference between temperatures $T_{d,fm}$ and $T_{k,fm}$ during the entire day. The dayly average absolute difference between mentioned temperatures for analyzed days are: 1.41°C (20.08.), 1.23°C (04.09.) and 1.64°C (04.10.).

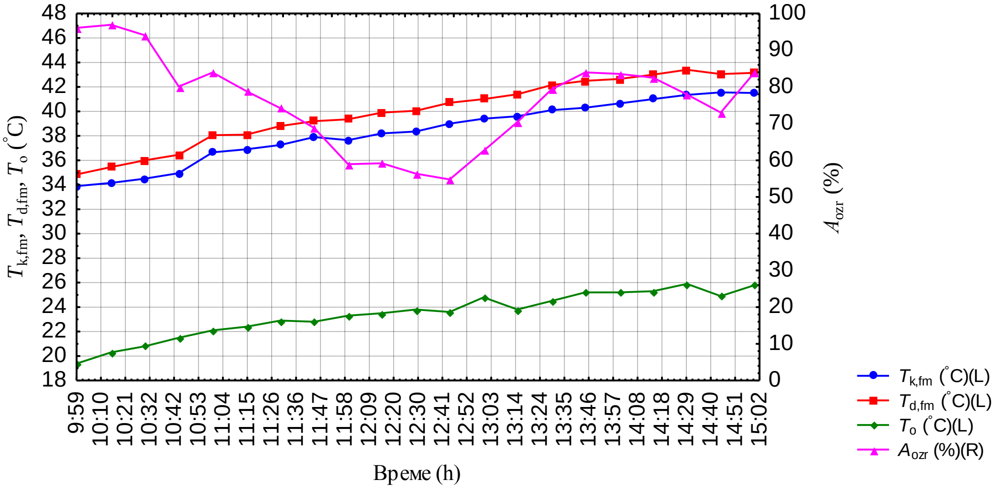

Figure 4 - Experimental diagrams of temperatures $T_{k,fm}$, $T_{d,fm}$, T_o and irradiation area A_{ozr} as a function of time for 04 October 2012.

Table 1 - The average value of irradiation area A_{ozr} (%) and percentage difference ΔQ (%) for periods of maximum achieved irradiation of LAS and for entire day

A_{ozr} (%)	**20.08.**	**04.09.**	**04.10.**
10:00-11:30 h	81.00	72.35	86.31
15:00-17:00 h (13:00-15:00 h)	73.53	76.15	77.48
Entire day	54.15	56.90	76.17
ΔQ (%)	**20.08.**	**04.09.**	**04.10.**
10:00-11:30 h	52.63	48.35	63.34
15:00-17:00 h (13:00-15:00 h)	70.32	74.54	73.20
Entire day	44.47	48.19	66.44

It is very difficult to compare the values of percentage difference and the difference of the mean fluid temperatures for different days because the testing conditions differed. The values of the inlet fluid temperature, the ambient temperature, the mass flow rates of the solar collectors, the intensity of the global horizontal radiation as well as the duration of the test differed. Analyzing the results, shown in the diagrams and in Table 1, it can be seen that the percentage difference of the heat power and the difference of the mean fluid temperature were higher in the afternoon than those in the morning, although the irradiation of the LAS were lower. This is explained by the fact that the percentage difference ΔI is higher in the afternoon due to a lower amount of diffuse radiation in total absorber radiation. According to the proposed theoretical model [3] the parameter A_{ozr} is related to the reflected direct solar radiation. In other words, for a particular value of A_{ozr} the difference ΔI will be higher if the proportion of the direct radiation in total absorbed radiation is higher and vice versa. Increasing of the difference of the heat power at the end of the testing can be explained by the existence of a transient effect. Causes of this effect are higher temperature of the DFPC system and its slightly larger dimensions, or heat capacity, in relation to the FPC system. The impact of the transient effect is the highest in the last hour of the testing, when the difference ΔQ increased even though the irradiation A_{ozr} decreased. As a rule, the same effect would be expected to exist at the beginning of the testing. Then, because of the higher heat capacity, a small amount of thermal energy would be used for heating a system of DFPC. On the above diagrams, for period at the beginning of the testing, the impact of this effect is very low. The data recording of the measured parameters was started at 10 a.m., although the instalation of DFPC and FPC had been put into operation earlier. If the testing had started in the moment when installation was put in operation the impact of the transient effect would have been higher. Before data recording the adjusting of the flow rate of the working fluid for the FPC and DFPC to the desired value was performed. It should be noted that during the testing the inlet water temperature of the solar collectors was not constant. Its value was adjusted according to the value of the ambient temperature. In other words, the value of the inlet water temperature was increasing during the entire day.

4. CONCLUSION

In this paper the experimental results of the mean fluid temperature of the conventional and double exposure flat-plate water solar collectors for the 20th August, 4th September and 4th October were presented and compared. By analyzing these results, it was concluded that the mean fluid temperature of the DEFPC is higher than the mean fluid temperature of the FPC during the entire day. This is because the total absorbed irradiation and thermal power of the DFPC are higher than the same for the FPC. The maximum value of the thermal power of the DFPC and difference between temperatures $T_{d,fm}$ and $T_{k,fm}$, for the instantaneous intensity of the global horizontal radiation, is related to the maximum value of the irradiated area of the LAS. The maximum achieved irradiation was in the morning and afternoon while the minimum aroun noon. In the periods of the maximum achieved irradiation the maximum percentage difference ΔQ was 48.35 % and 74.54 %, while the maximum absolute difference between temperatures $T_{d,fm}$ and $T_{k,fm}$ was 2.17°C and 1.87°C, respectively.

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