TOPLOTNA SNAGA DVOSTRUKO OZRAČENOG I KLASIČNOG RAVNOG VODENOG PRIJEMNIKA SUNČEVE ENERGIJE - EKSPERIMENTALNI REZULTATI

THERMAL POWER OF THE DOUBLE EXPOSURE AND THE CONVENTIONAL FLAT-PLATE WATER SOLAR COLLECTORS - EXPERIMENTAL RESULTS

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Apstrakt: U okviru ovog rada prikazani su rezultati eksperimentalnog ispitivanja dvostruko ozračenog i klasičnog, ravnog vodenog prijemnika sunčeve energije. Rezultati se odnose na toplotnu snagu ova dva prijemnika. Dvostruko ozračeni prijemnik je prijemnik koji može apsorbovati solarno zračenje gornjom kao i donjom površinom apsorbera. Apsorpcija donjom površinom apsorbera omogućena je upotrebom ravnog reflektora. Reflektor je postavljen ispod i paralelno sa prijemnikom. Eksperimentalna ispitivanja sprovedena su tokom meseca avgusta, septembra i oktobra 2012. godine. U okviru ovog rada prikazani su eksperimentalni rezultati za 04. septembar. Nakon poređenja dobijenih rezultata za oba prijemnika zaključeno je da je toplotna snaga dvostruko ozračenog prijemnika veća od iste klasičnog prijemnika. Povećanje toplotne snage varira između 18.11-69.29 %. Dnevno povećanje toplotne snage i količine toplote iznosi 48.19 i 43.36 %, respektivno.

Ključne reči: dvostruko ozračen prijemnik sunčeve energije, reflektor, eksperiment

Abstract: In this paper the results of the experimental testing of the double exposure flat-plate and the conventional flat-plate water solar collectors are presented. The results are related to the thermal power of these two solar collectors. The DFPC is a solar collector which can absorb solar radiation by upper as well as lower absorber surface. Absorption from lower surface is enabled by application of a flat-plate reflector. The reflector is placed below and in parallel with the collector. The experiments were performed in the months of August, September and October in 2012. In this paper the resuts of the experiment for the 4th September are presented. After comparison of the obtained results for both solar collectors it was concluded that the thermal power of the DEFPC is higher then the same for the FPC. The increase of the thermal power varied in the range 18.11-69.29 %. The dayly increase of the thermal power and thermal energy is 48.19 and 43.36 %, respectively.

Key words: double exposure flat - plate 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 below the collector. On the other side, absorption from the upper absorber surface is the same as that in the conventional flat-plate collector (FPC). 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 experimental results of the testing of the double exposure and conventional solar collectors are presented. The results are related to their thermal power.

2. EXPERIMENT

On the Fig. 1 the experimental installations of the tested solar collectors are presented. Both installations are mounted on the vertical south-west wall of the open area of the Thermodynamics and Thermotechnics Laboratory of the Faculty of Engineering Kragujevac.

Fig. 1. Experimental installation of the double exposure (left) and conventional solar collector (right)

The DEFPC and FPC were tested for different water mass flow rates and different values of the water inlet temperature. The experimental installations are open while the water from the water supply system was used as a working fluid. Both solar systems were set up at the tilt angle $G = 36^{\circ}$ and orientation $\alpha = 147^{\circ}$. 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 same solar collectors. The reflector was moved manually every hour during the testing.

Every day of the testing tha data about the instantaneous global horizontal radiation, the ambient temperature, the inlet and outlet water temperatures and the mass flow rates 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

The experimental tests of both solar collectors were performed during August, September and October of the 2012. In this paper the experimental results and diagrams for the 4th September are presented. For the mentioned date the water mass flow rates of both solar collectors are approximetely the same as the recommended water mass flow rates for the size of absorber of 0.3864 m^2. The recommended water mass flow rate is defined via the mass flow flux as 0.015 kg/sm^2 [3]. Thus, the recommended water mass flow rate for the size of the absorber of 0.3864 m^2 is 0.005796 kg/s.

In Table 1 and 2 the experimental results of the solar collectors are presented. The data about water mass flow rates (m_k and m_d), the inlet water temperatures ($T_{k,u}$ and $T_{d,u}$), the outlet water temperatures ($T_{k,i}$ and $T_{d,i}$) and thermal power (Q_k and Q_d) of the solar collectors are given in Table 1. In Table 2 the data about the ambient temperature (T_o), the global horizontal radiation (H'), the wind speed (V_{vetra}), the irradiated area of the LAS in m^2 and % (A_{ozr}) as well as the percentage difference between the thermal powers of the solar collectors (Q_d-Q_k) are given.

Table 1. Experimental results of the FPC and DEFPC for the 4th September 2012: m_k (m_d), $T_{k,u}$ ($T_{d,u}$), $T_{k,i}$ ($T_{d,i}$) i Q_k (Q_d)

Time (h)	m_k (kg/s)	$T_{k,u}$ (°C)	$T_{k,i}$ (°C)	Q_k (W)	m_d (kg/s)	$T_{d,u}$ (°C)	$T_{d,i}$ (°C)	Q_d (W)
10:00	0.00616	34.3	38.8	115.95	0.00616	34.1	41.3	185.508
10:15	0.00616	34.5	40	141.711	0.00616	34.3	42.2	203.537
10:30	0.00616	34.7	40.5	149.438	0.00616	34.4	43.3	229.293
10:45	0.00616	35	41.1	157.163	0.00616	34.7	44.2	244.742
11:00	0.00616	35.2	42	175.193	0.00616	34.9	44.8	255.041
11:15	0.00582	35.4	42.5	172.822	0.00581	35.2	45.3	245.404
11:30	0.00582	35.6	42.9	177.687	0.00581	35.3	45.4	245.402
11:45	0.00582	35.8	44.1	202.019	0.00581	35.5	45.7	247.828
12:00	0.00582	35.9	44.4	206.885	0.00581	35.7	46.6	264.828
12:15	0.00582	36.4	44.6	199.579	0.00581	36.1	46.1	242.962
12:30	0.00582	36.6	45.8	223.908	0.00581	36.3	46.8	255.103
12:45	0.00582	37.1	46	216.602	0.00581	36.8	47	247.809
13:00	0.00582	37.2	46.3	221.467	0.00581	36.9	47.2	250.237
13:15	0.00582	37.3	46.3	219.033	0.00581	37	47.6	257.521
13:30	0.00582	37.6	47	228.761	0.00581	37.3	48.5	272.088
13:45	0.00569	37.5	46.7	218.895	0.00564	37.2	50	301.847
14:00	0.00569	37.6	46.9	221.272	0.00564	37.2	50.6	315.99
14:15	0.00569	38	46.9	211.753	0.00564	37.6	50.8	311.268
14:30	0.00569	38.2	46.9	206.993	0.00564	37.8	51.4	320.693
14:45	0.00569	38.2	46.5	197.479	0.00564	38	51	306.547
15:00	0.00569	38.7	46.5	185.58	0.00564	38.4	50.9	294.754
15:15	0.00569	39.1	46.5	176.061	0.00564	38.6	51.4	301.822
15:30	0.00569	39.4	46.5	168.921	0.00564	39	51.1	285.315
15:45	0.00569	39.6	46.4	161.783	0.00564	39.1	50.3	264.099
16:00	0.00569	39.9	45.6	135.615	0.00564	39.4	49.6	240.521
16:15	0.0055	40.3	45.8	126.484	0.00549	39.7	49.4	222.647
16:30	0.0055	40.7	45	98.889	0.00549	40.1	47.7	174.452
16:45	0.0055	41	44.6	82.791	0.00549	40.3	46.9	151.5
17:00	0.0055	41.5	44	57.4939	0.00549	40.8	45.7	112.48

Table 2. Experimental results of the FPC and DEFPC for the 4th September 2012: T_o, H', V_{vetra}, A_{ozr} (m^2 and %) and Q_d-Q_k

Time (h)	T_o (°C)	H' (W/m^2)	V_{vetra} (m/s)	A_{ozr} (m^2)	A_{ozr} (%)	Q_d-Q_k (%)
10:00	26.8	608	1.9	0.359	92.91	59.99
10:15	27.3	635		0.3465	89.67	43.63
10:30	27.1	659		0.3065	79.32	53.44
10:45	27.8	680		0.2652	68.63	55.72
11:00	28.3	698	2	0.2783	72.02	45.58
11:15	28.8	713		0.2266	58.64	42
11:30	29	725		0.1748	45.24	38.11
11:45	29.9	734		0.123	31.83	22.68
12:00	30.2	739	2	0.1118	28.93	28.01
12:15	30.6	742		0.0774	20.03	21.74
12:30	31.2	742		0.0449	11.62	13.93
12:45	31	738		0.0214	5.538	14.41
13:00	31.4	732	2.2	0.0671	17.37	12.99
13:15	32	722		0.0941	24.35	17.57
13:30	32.2	710		0.1343	34.76	18.94
13:45	32.1	694		0.1722	44.57	37.9
14:00	32.8	676	2.4	0.1995	51.63	42.81
14:15	33	654		0.2232	57.76	47
14:30	33.3	629		0.2431	62.91	54.93
14:45	33.4	601		0.2589	67	55.23
15:00	32.7	571	2.6	0.3376	87.37	58.83
15:15	33.3	537		0.3501	90.61	71.43
15:30	32.8	500		0.3381	87.5	68.9
15:45	33.2	460		0.3009	77.87	63.24
16:00	32.9	417	2.7	0.3307	85.58	77.36
16:15	33.2	371		0.2818	72.93	76.03
16:30	32.8	322		0.2298	59.47	76.41
16:45	32.9	269		0.1749	45.26	82.99
17:00	32.1	214	2.1	0.3044	78.78	95.64

Comparative diagrams of the thermal powers of the analyzed solar collectors are shown on Fig. 2. On the same figure the diagram of the percentage difference between thermal powers as well as the diagram of the irradiated area of the LAS of the DEFPC in % are given too.

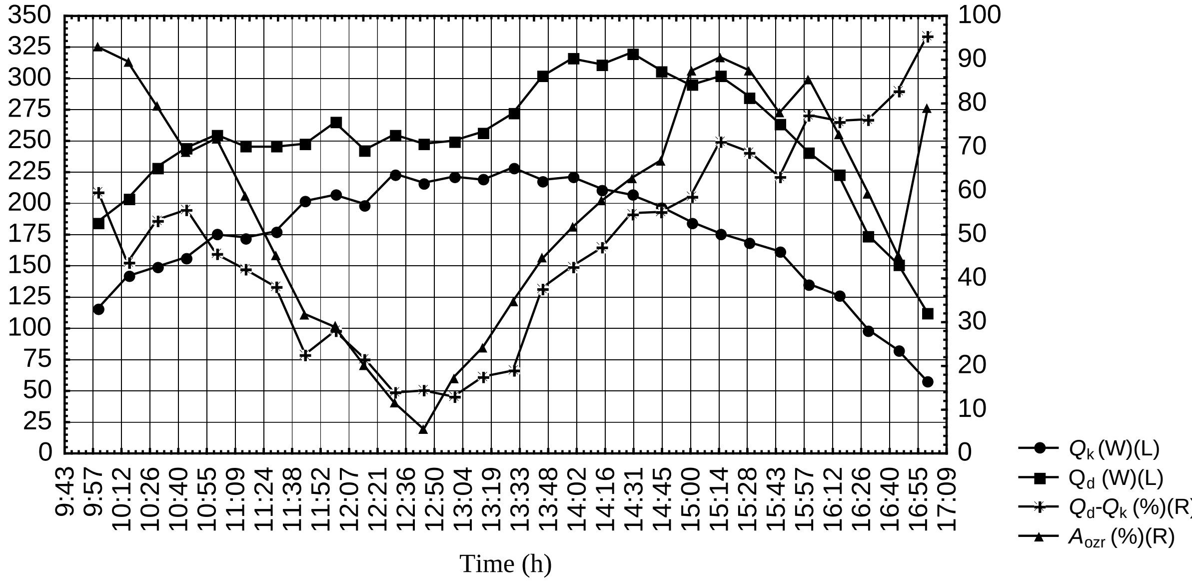

Fig 2. Diagrams of the thermal powers of the FPC and DEFPC, their percentage difference and the irradiated area of the LAS of the DEFPC in %

The great impact on the value of the thermal powers Q_k and Q_d has the total absorbed radiation I_k and I_d. The FPC absorbs solar radiation by its upper absorber surface while the DEFPC can absorb solar radiation simultaneously from both its upper and lower absorber surfaces. In relation with that the greatest impact on the value of the absorbed radiation of the DEFPC (I_d) has the value of the irradiated area of the LAS. The condition for the maximum I_d, for the instantaneous intensity of the global horizontal radiation, is full irradiation of the LAS. Due to the manual movement of the reflector and the fact that it was the only location for mounting the DEFPC it was not possible in most cases to provide a full irradiation of the LAS. From Fig. 2 it can be concluded that the minimum irradiation of the LAS was around noon while the maximum in the morning and afternoon. The maximum possible values of the irradiation area of the LAS during experiment are given in Table 2. Notwithstanding the above it can be noticed that the value of the thermal power Q_d throughout the daytime was always higher then the value of the Q_k. The values of the percentage difference between Q_d and Q_k for the analyzed date are given in Table 2. The diagrams from the Fig. 2 shows that the percentage difference between thermal power of the solar collectors is higher in the afternoon than the one in the morning. The reason for this is that the percentage difference between I_k and I_d is higher in the afternoon because the solar collectors are oriented toward the west as well as the irradiation area of the LAS is slightly higher. Also, the percentage difference between thermal powers is the highest at the end of the testing. That is because of a transient effect in the DEFPC. In that period the inlet water temperature was highest during the day. The decreasing of the incoming solar radiation caused the decreasing of the value of the mean water temperature. The rate of decreasing of this temperature was lower for the DEFPC than for the FPC. In this way, the percentage difference between heat losses of the DEFPC and FPC was lower.

In the period from 10:00 to 11:00 h and 15:00 - 16:15 h the irradiation of the LAS was the highest during the day. The value of the average irradiation of the LAS for the mentioned periods is 80.51 % and 83.64 %, while the value of the average percentage difference between thermal powers is 51.67 % and 69.29 %, respectively. On the other hand, the lowest irradiation of the LAS was in the period from 12:00 to 13:15 h. For this period the value of the average irradiation of the LAS is 17.97 %, while the value of the average percentage difference between thermal powers is 18.11 %.

Looking for the whole day the dayly irradiation of the LAS and the dayly percentage difference between thermal powers is 56.89 % and 48.19 %, respectively. The total amount of heat delivered to the working fluid of the FPC and DEFPC during the whole day is 4.55 MJ and 6.53 MJ, respectively. In this respect, the percentage difference between heat energies is 43.36 %.

4. CONCLUSIONS

In this paper the experimental results of the thermal power of the conventional and double exposure flat-plate water solar collectors for the 4th September are presented and compared. By analyzing these results, it was concluded that the thermal power of the DEFPC is higher than the the thermal power of the FPC during the whole day. The great impact on the value of the thermal power of the DEFPC has the value of the irradiated area of the LAS. The maximum value of the thermal power, for the instantaneous intensity of the global horizontal radiation, is related to the maximum value of the irradiated area of the LAS. Because of the above mentioned limitations it could not be possible to have full irradiation of the LAS in most cases during the 4th September. Thus, the maximum possible irradiation was in the morning and afternoon while the minimum aroun noon. In the periods of the maximum possible irradiation the value of the percentage difference between thermal power of the DEFPC and FPC is 51.67 % and 69.29 %, respectively. On the other hand, in the period around noon the value of the same difference is 18.11 %. Regarding the total amount of heat delivered to the working fluid of the DEFPC and FPC during the whole day, the one for the DEFPC is 43.36 % higher than the same for FPC.

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