SUBSTANTIATION FOR CONSTRUCTION OF SOLAR COLLECTOR WITH REFLECTORS

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Abstract. The research of a solar collector with reflectors was performed. Considering this type of the solar collector it is important to evaluate the geometric parameters and position of irradiated solar collector. The article deals with analyzes of implication of the mirror distance and the rotation angle to the collector efficiency. The article presents the foundation of the right and left side mirror rotation angle to the collector surface. The angle is dependent on the mirror size, and the placement distance from the collector is shown.

Keywords: solar radiation, solar collector, reflectors, angle.

Introduction

The greatest advantage of solar energy comparing with other forms of energy is that it is clean and can be supplied without environmental pollution. Solar energy is used to heat and cool buildings (both actively and passively), dry products, heat water for domestic and industry use, heat swimming pools, generate electricity for chemistry applications and many other operations [1].

The application of solar energy is completely dependent on solar radiation, a low-grade and fluctuating energy source. In general, solar water heaters are flat-plate collectors. An intrinsic difficulty in using solar energy is caused by the wide variation in the solar radiation intensity.

To obtain the additional radiation the reflectors (mirrors) are used. Particularly wide mirrors are used for the spherical collectors [2], but those have been studied less for the flat plate solar collectors. Practical researches on the usage of additional radiation were performed at the Research Institute of Agricultural Machinery [3]. The research experiment has shown the increase of the efficiency of a collector, irradiating the collector plane with the addition of solar radiation by the gain from the additional reflectors.

The aim of the research was to find the influence of the mirror distance and rotation angle to the collector working efficiency and the angles dependence on the mirror size and the distance to the placement of the solar collector.

Materials and methods

Flat-palate solar collectors receive solar energy directly from the sun, the typical flat-plate solar collector receives solar radiation through the transparent cover. In order to increase the received amount of energy the reflecting mirrors can be used, in addition to irradiate the collector surface, thereby increasing the common solar irradiance.

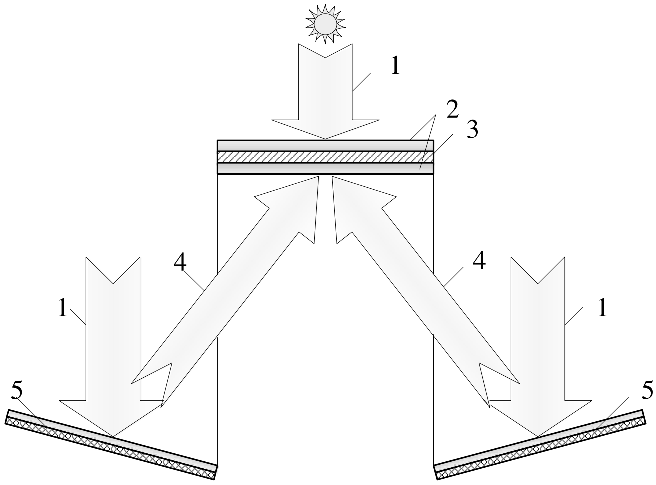

Fig. 1. **Principal scheme of solar collector with reflectors:** 1 – falling sun rays, 2 – collector cover (glass), 3 – absorber, 4 – reflection sun rays, 5 – reflectors

For the experimental research was constructed the solar collector with reflectors was constructed [4]. The absorber (3) positioned in the middle of the collector, and the collector cover (glass) (2) placed on either side of the collector (Fig. 1). The solar collector with reflectors (5) has been merged into one single framework, and their location influenced the angle of incidence of solar radiation.

The absorber plate receives direct solar radiation (1) and reflective (or additional) radiation (4) from the reflectors.

Results and discussion

Firstly, we determined the rotation angles of the mirror for solar incident rays, reflecting from the mirror, projected to the absorber of the solar collector. For this reason the left mirror rotation angle detection scheme was created (Fig. 2).

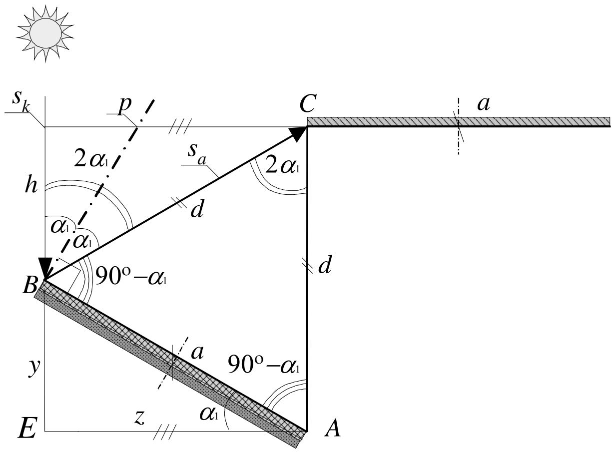

Fig. 2. **Detection scheme for left mirror rotation angle α_1**

Suppose that the length of the absorber and mirror are equal – *a*. To comply the rules, provided that after mirror rotation the right side point *A* is located directly in front of the absorber point *C*. Consider that the mirror must be positioned so that to the mirror point *B* the falling solar ray s_k is reflected to the absorber point *C*. The distance from the absorber point *C* to the mirror point *A* is denoted by *d*. The light reflection angle equals the angle of incidence of light. So, changing the mirror rotation by α_1, the incident ray s_k on the point *B* made an angle α_1 with mirror perpendicular *p*, and the reflected ray s_a with perpendicular *p* forms an angle α_1. Thus, the angle between the incident and reflected rays will be equal to $2\alpha_1$.

From Δ *ABC* followed that *AC* = *BC*= *d.* Using the cosine theorem $a^2 = 2d^2 - 2d^2 \cdot \cos 2\alpha_1$ we find the rotation angle α_1 dependence on the mirror length *a,* and the placement distance *d*:

$$\sin \alpha_1 = \frac{a}{2d^2}, \tag{1}$$

or

$$\alpha_1 = \arcsin \frac{a}{2d}. \tag{2}$$

Consider a right-angled triangle *ABE* (Fig. 2), where the side *AE* is the projection of the mirror to the horizontal axis-*z*. From Δ *ABE* follows that: $z = a \cdot \cos\alpha_1$, and the distance from the left edge of the mirror to the projection $y = z \cdot \mathrm{tg}\alpha_1$. While the size of *h* can be expressed:

$$h = d - a \cdot \sin \alpha_1. \tag{3}$$

Similarly the position of the right side mirror can be obtained. Assume that the reflected ray from left point *G* of the right mirror falls on the left side of the absorber point *C* (Fig. 3).

Describing a rotation angle of the mirror with α_2, the angle between the incident ray s_k and reflected ray s_a will be equal to $2\alpha_2$. Δ *CGD*, with the already known values *a* and *d*, determined the angle α_2:

$$\mathrm{tg}\, 2\alpha_2 = \frac{a}{d}, \tag{4}$$

or

$$\alpha_2 = \frac{1}{2}\mathrm{arctg}\frac{a}{d}. \tag{5}$$

At the constant position of the collector the reflective angle from the point *H* will reflected outside of the absorber plane. It will reflected on the right point *D* of the absorber when the Earth turned after some moment of time.

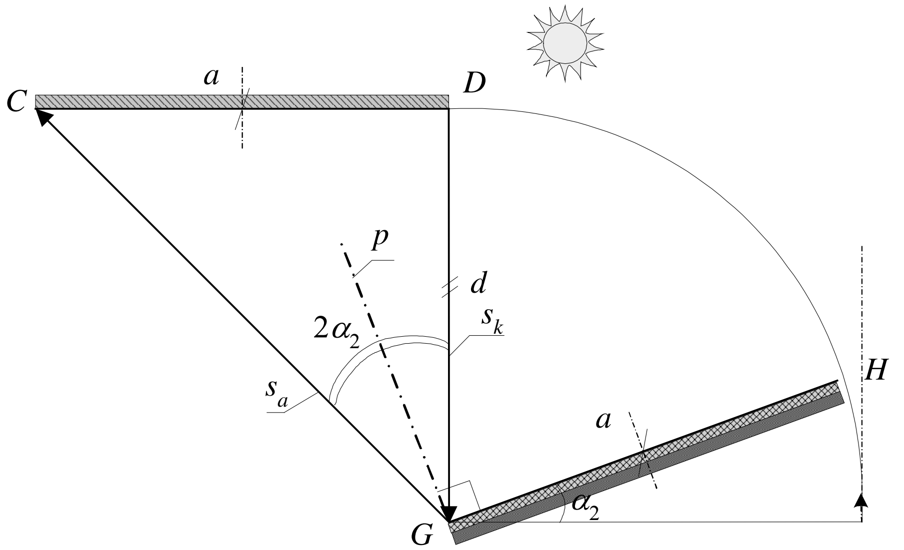

Fig. 3. **Detection scheme for right mirror rotation angle α_2**

As a result of finding correlations (2) and (5), we see that the right and left side mirror placement angle depends on the size of the collector absorber length *a* and placement distance *d*. For produced practical devices Table 1 and Table 2 can be used, which shows the minimum allowable right side (Table 2) and maximum allowable left side (Table 1) mirror angles.

The values *a* and *d* are the relative absorber and mirror distance. If both are the same (diagonal in tables) the rotation angle of the right mirror $\alpha_1 = 22.5°$ and of the left mirror $\alpha_1 = 30°$. As we can see, the right and left side mirror rotation angle is not the same. This can be explained by the fact that α_1 – maximum the possible angle of rotation and α_1 – minimum possible angle of rotation.

Table 1

Estimates of mirror rotation angle α_1

d	***a***									
	0.1	*0.2*	*0.3*	*0.4*	*0.5*	*0.6*	*0.7*	*0.8*	*0.9*	*1.0*
0.1	**30**	87	-	-	-	-	-	-	-	-
0.2	14.32	**30**	48.59	87	-	-	-	-	-	-
0.3	9.55	19.47	**30**	41.81	56.44	87	-	-	-	-
0.4	7.16	14.48	22.02	**30**	38.68	48.59	61.04	87	-	-
0.5	5.73	11.53	17.45	23.58	**30**	36.87	44.43	53.13	64.16	87
0.6	4.77	9.59	14.48	19.47	24.62	**30**	35.69	41.81	48.59	56.44
0.7	4.09	8.21	12.37	16.60	20.92	25.38	**30**	34.85	40.01	45.58
0.8	3.58	7.18	10.81	14.48	18.21	22.02	25.94	**30**	34.23	38.68
0.9	3.18	6.38	9.59	12.84	16.13	19.47	22.89	26.39	**30**	33.75
1.0	2.86	5.73	8.63	11.54	14.48	17.46	20.49	23.58	26.74	**30**

Table 2

Estimates of mirror rotation angle α_2

d	*a*									
	0.1	*0.2*	*0.3*	*0.4*	*0.5*	*0.6*	*0.7*	*0.8*	*0.9*	*1.0*
0.1	**22.5**	31.72	35.78	37.98	39.35	40.27	40.93	41.44	41.83	42.14
0.2	13.28	**22.5**	28.15	31.72	34.10	35.78	37.03	37.98	38.74	39.35
0.3	9.22	16.85	**22.5**	26.57	29.52	31.72	33.40	34.72	35.78	36.65
0.4	7.02	13.28	18.43	**22.5**	25.67	28.15	30.13	31.72	33.02	34.10
0.5	5.66	10.90	15.48	19.33	**22.5**	25.10	27.23	28.99	30.47	31.72
0.6	4.73	9.22	13.28	16.85	19.90	**22.5**	24.70	26.57	28.15	29.52
0.7	4.07	7.97	11.60	14.87	17.77	20.30	**22.5**	24.41	26.06	27.50
0.8	3.56	7.02	10.28	13.28	16.00	18.43	20.59	**22.5**	24.18	25.67
0.9	3.17	6.26	9.22	11.98	14.53	16.85	18.94	20.82	**22.5**	24.00
1.0	2.86	5.65	8.35	10.90	13.28	15.48	17.50	19.33	20.99	**22.5**

The corresponding mirror angles dependence is shown in Fig. 4.

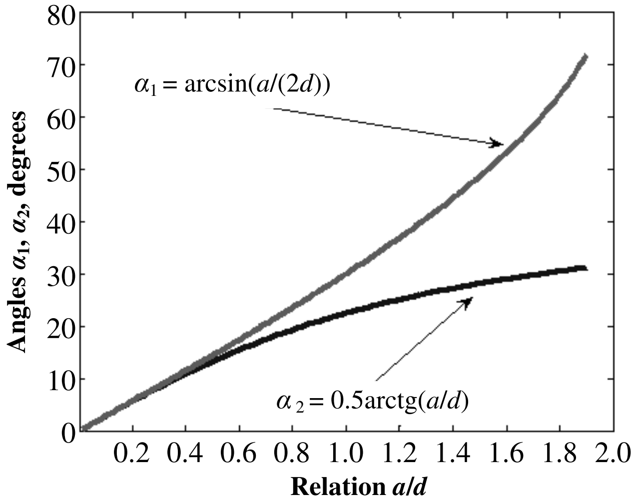

Fig. 4. **Dependence of right side and left side mirror angles**

As it can be seen at low *a* and *d* relations the rotation angles differ little from each other. Starting with the ratio of 0.6, this difference begins to increase significantly (Fig. 4), where the ratio 1.7 the left angle (maximum angle) becomes three times higher for the right side angle (the minimum allowable angle). Using these angles it is possible to determine the time interval, the collector absorber is fully irradiated from the mirror collector while in a stationary position.

Conclusions

1. Assuming that the mirror and absorber are equal, min and max mirror angle placement is found.
2. Using the resulting relationships the placement an appropriate distance from the mirror at a certain angle can be detected.
3. Continuing research, the obtained values will provide an opportunity to determine turning the mechanism of the solar collector with reflectors.

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