MIRROR-COLLECTOR FOR SOLAR WATER HEATING

Liene Kancevica, **Henriks Putans**, **Imants Ziemelis**
Latvia University of Agriculture, Research Institute of Agricultural Machinery
Imants.Ziemelis@llu.lv

Abstract. In order to increase the efficiency of a flat plate solar collector it is recommended to equip it with two mirrors so that the reflected from the mirrors solar radiation strikes the rear surface of the collector. In the collector box only an absorber with a heat exchanger are placed. Both sides of the box are covered with glass panes. The collector and mirrors on a common frame are fastened. The frame on a sloping axle is mounted. The axle by an electric motor and gear-box is driven automatically by means of a step-shaped voltage generator. Such a construction secures that the solar collector's surface is tracing the sun all the day round and solar rays are striking it perpendicularly.

Key words: solar radiation, solar collector, mirrors, tracking the sun, efficiency.

Introduction

In many countries all over the world solar energy is used for air and domestic water heating, drying needs, production of electricity and biomass growing. For water heating mainly flat plate collectors are used as they are cheaper in production and exploitation [1]. The efficiency of up-to-date flat plate solar collectors, the working surface of which is covered with special selective coating, can reach 0.4 and more [1; 2]. Regardless of that such efficiency for Latvia weather conditions is not enough. On the average we have about 1800 sunny hours a year [3]. The total energy of the solar radiation on the horizontal surface in the different regions of Latvia is equal to 400 – 500 kWh/m^2 per sunny summer day. This value corresponds to 1000 kWh/m^2 per year or about 800 kWh/m^2 of heat energy from April to September. The maximum of solar radiation on the horizontal surface in July is about 600 W/m^2 at the average cloudiness and about 800 W/m^2 in a sunny day. Research and calculations prove that solar radiation intensity in Latvia in summer months is enough to produce hot water for different applications [4].

The goal of our investigation was to look for possibilities to increase the efficiency of a flat plate solar collector by the intensification of radiation falling on the collector's absorber.

Materials and methods

The efficiency of the solar collector can be increased by treating with solar rays both surfaces of the absorber – the front surface by direct radiation and rear one by rays reflected from mirrors. In this case it is possible to get more heat energy from each m^2 of the collector area. The amount of additionally obtained heat depends on the size and quality of the mirrors' surface. There both sides of the absorber have to be painted in black color or covered by specific coating facilitating the absorption of solar energy. The collector and mirrors have to be joined into the common system tracking the sun.

A flat plate solar collector usually consists of a box-shape frame with a cover from the bottom side. In the box the layer of heat insulation and heat absorber (metal plate) with a heat exchanger are placed. In order to avoid the heat losses by convection from the front side of the absorber the collector box is covered by transparent (glass pane) cover (Fig. 1a). According to our proposal in the collector box only an absorber with a heat exchanger are placed and both sides of the box are covered by glass panes (Fig. 1b). Both sides of the absorber plate are covered with radiation absorbing layer (or painted in black) and for irradiation of the absorber's rear surface, two mirrors are located at both sides of the collector. The mirrors and the collector are fixed on a common frame and the mirrors are oriented so that falling on them the solar radiation is reflected on the rear side of the absorber, i.e., at the opposite side of the sun (Fig. 2). So both sides of the absorber are having the solar radiation.

So that the sun rays are striking the collector surface perpendicularly all the day round the collector has to follow the movement of the sun. It means the position of the collector has to be changed in two planes – horizontal and vertical. The system for automatic management of such a process is rather complicated. It is possible to simplify it by automatic turning the solar collector only in the sun's orbit plane. In this case the angle of the orbit plane is changed manually only one or two times a week.

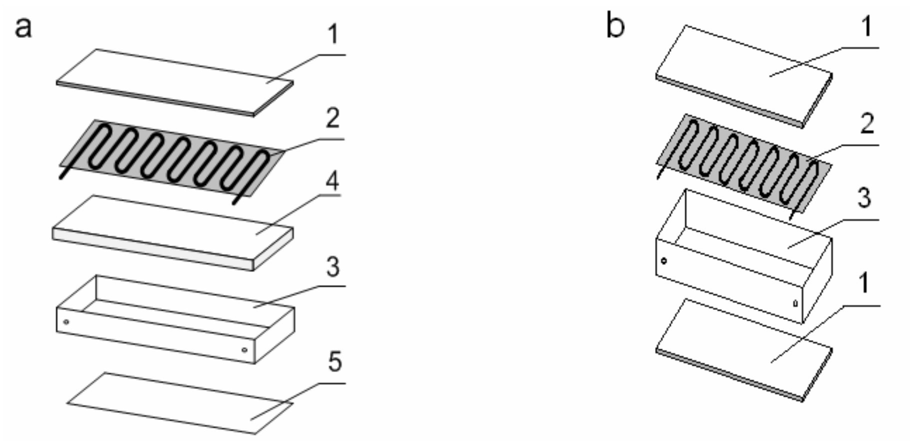

Fig. 1. **Schemes of solar collectors**: a – usual flat plate solar collector; b – collector for mirror-collector device; 1– glass pane; 2 – absorber with heat exchanger; 3 – collector box; 4 – heat insulation; 5 – cover

Fig. 2. **Mirror-collector on the roof of a house at Ulbroka**

Results and discussion

Practically it is possible to implement such a principle by turning the collector around the slanting axle directed to the North Star. The axle has to be put on the slope under angle 90-φ, where φ – the degree of the latitude of the place. If the surface of the collector is parallel to the axle, the sun rays will strike the collector surface perpendicularly on March 21 and September 21. So that the surface of the collector is perpendicular to the sun rays all the day round, the angle between horizontal and absorber plate in spring gradually has to be decreased, in summer and autumn – increased and in winter decreased again.

There different schemes of automatic control of the system's work can be used. The scheme used in our case for self-acting management of the device is presented in Fig. 3. It is supplied with a step-shaped voltage generator *Ug*, operational intensifier *DA* and an electric motor with a gear-box (*MR*). The direction of the rotation of the electric motor is dependent on the polarity sign of the supplied voltage and alter-resistance *R*. During round-the-clock the generator *Ug* makes 72 voltage increments (steps) with the time intervals of 15 min. From each of the steps the frame of the device with the system collector-mirrors turns by 5^o to the direction of the sun's movement. At night, when the step-shaped voltage runs to zero, the system collector-mirrors, turning in opposite the sun's movement direction, returns to the starting position. The voltage generator *Ug* has manual (distance) control button *SA*, which is envisaged for the fast orientation of the device to the sun.

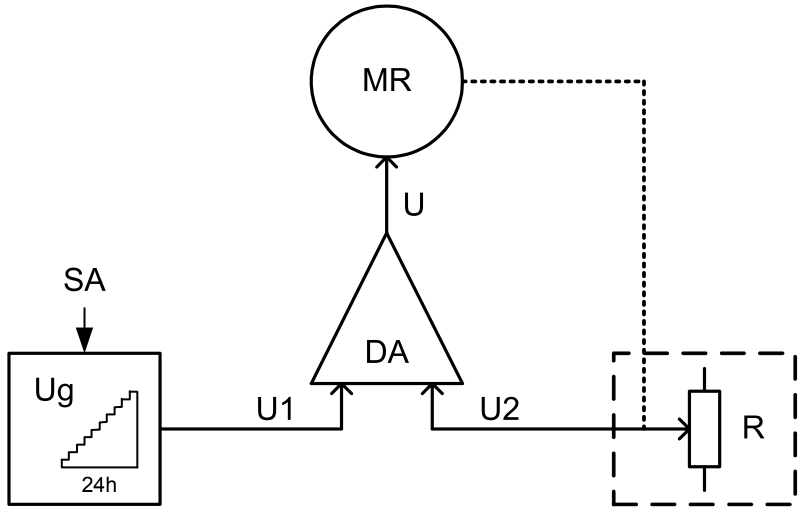

Fig. 3. **Scheme of self-acting management**: *MR* – motor-gear-box unit; *SA* – manual control button; *Ug* – step-shaped voltage generator; *DA* – operational intensifier; *R* – alter-resistance; *U*, *U1*, *U2* – voltage

The collector device comprises the frame 1, where between the side balks the flat-plate solar collector 2 is fixed (Fig. 4). In the collector box 13 there the absorber 14 with the heat exchanger is placed. Both sides of the box are covered by panes of glass 15. Two mirrors 3 and 4 are fastened to the frame 1. The collector and mirrors are secured symmetrically and perpendicularly to the frame plane. In the nests of the frame's bearings a balk 5 is placed, which in its centre immovably on the axle of the gear-box 6 is fastened, but the gear-box in its turn immovably on a support 7 is fixed. Into the frame 1 a cross-beam 8 is immovably assembled. The bulk 5 and the cross-beam 8 are mutually connected by means of a screw mechanism 9, which have a handle 10. In order to work automatically, the device is provided with an electric motor 11 and alter-resistance (potentiometer) 12, the transmission axle of which with the secondary axle of the gear-box 6 is coupled.

In order to start and control the system, at the middle of a sunny day by the gear-box manual drive *SA* (Fig. 3) and the screw mechanism 9 (Fig. 4) the collector have to be positioned perpendicularly to the sun rays. For the control of this situation the collector device is equipped with the back site 16 – the bended strip of steel. In one of its ends there a bore is drilled, but on another one – the point is painted. When the sun rays going through the bore at one end of the steel strip are falling on the point at another end of the strip, it means that the surface of the collector is in correct position – perpendicular to the sun rays.

The gear-box drive mechanism will not rotate if the voltage on the electric clamps $U = 0$ (Fig. 3). But it will occur if $U1 = U2$. During 24 hours the voltage *U1* will gradually increase from 0 up to its maximum value, which will be reached at 24 o'clock. After that it again will decrease until zero. If the voltage $U1 > U2$, the exit voltage of the operational intensifier (*DA*) *U* is conditionally positive and the electric motor will turn the collector in the direction of the movement of the sun. If the voltage $U1 < U2$, the rotation will be in opposite direction until the voltage *U1* decreases till zero and stops in the North direction. If the voltage *U1* decreases by 1 step, for example, 0.1 V, at the exit of the operational intensifier will be positive voltage *U* and the collector will be turned in the sun's movement direction for certain angle, for example, 5 degrees. So during round-the-clock the collector will be turn in the sun's movement direction by 360^o and at midnight will be turned back. If one step of rotation 5^o is chosen, then the number of rotation steps at the maximum of voltage *U1* value is 360^o : 5^o = 72, but the maximum value of the voltage $U1_{max}$ = 72 · 0.1 = 7.2 V. In the electric scheme of the generator it is possible to include the voltage *U1* restrictor from both sides and then the angle of rotation of the collector during twenty four hours will be less then 360^o and changeable, for example, from 100 to 240 degrees.

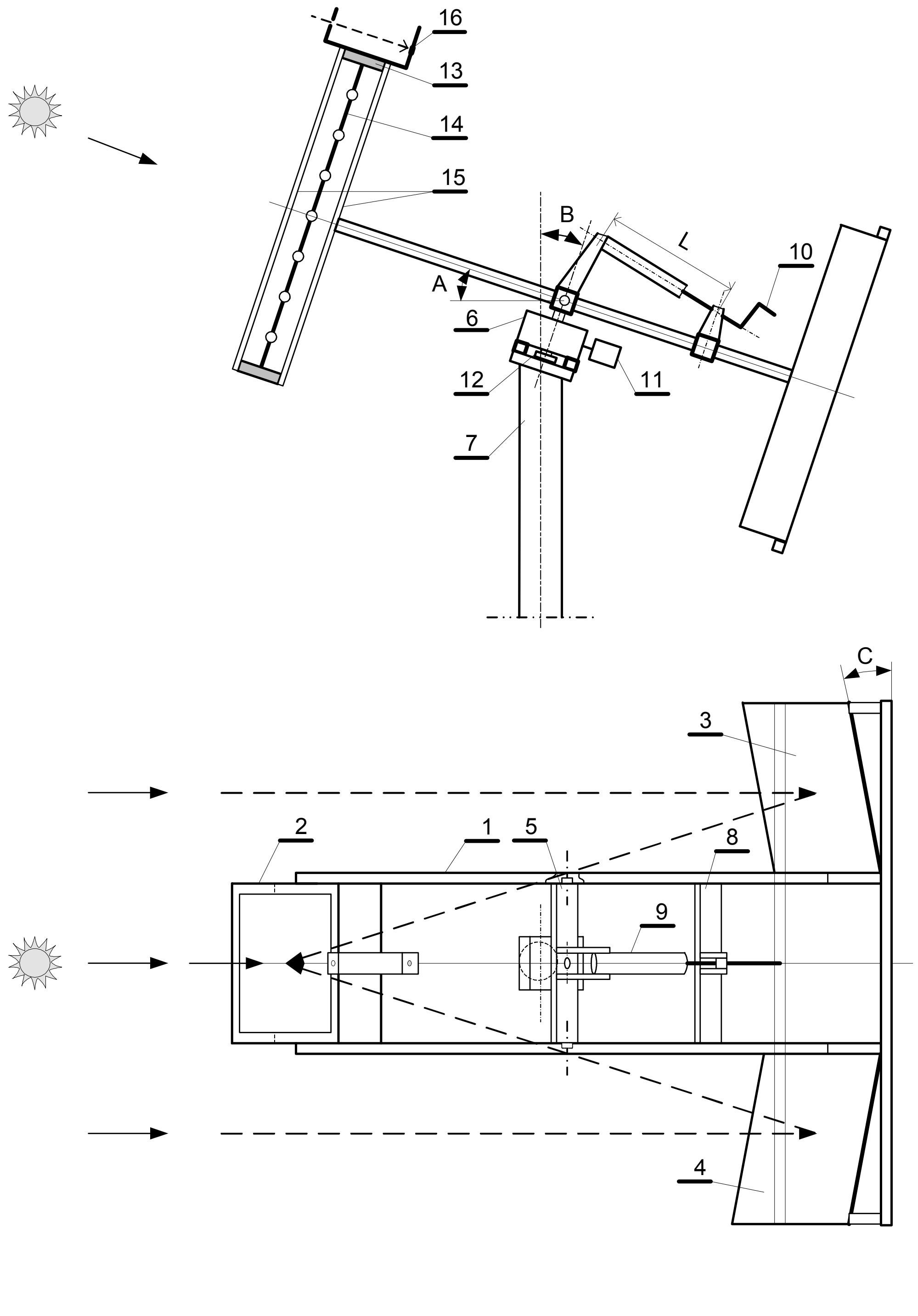

Fig. 4. **Kinematical scheme of the mirror-collector**: 1 – frame; 2 – solar collector; 3 and 4 – mirrors; 5 – balk; 6 – gear-box; 7 – support; 8 – cross-beam; 9 – screw mechanism; 10 – handle; 11 – electric motor; 12 – alter-resistance (potentiometer); 13 – collector box; 14 – absorber with heat exchanger; 15 – glass panes; 16 – back site; *A* – slope angle of the frame; *B* – angle of the North Star; *L* – distance

If the coefficient of reflection for solar radiation of the mirrors is assumed to be equal to 1 and the surface area of each of mirrors is equal to the area of the collector, the efficiency of the collector has to be 3 times higher than of the collector without mirrors. Our experimental investigation carried out in Ulbroka during the summer 2005 has shown, that the heat yield obtained from the mirror-collector tracking the sun is 2.1 times bigger than that, obtained from the same collector working at stationary position. The decrease of the heat energy obtained in the experiment is due to lower value of the coefficient of reflection than one for real mirrors. In our experimental mirror-collector the surface of each of mirrors was equal to the surface of the absorber. In general the construction of the mirror-collector allows the usage of bigger plane or parabolic mirrors then the collector area, so increasing the intensity of solar radiation at the rear surface of the absorber. Instead of glass mirrors it is possible to use the sheets of polished stainless steel which will make the construction more safe and cheaper.

In order to clear up the economical profitableness of the use of the mirror-collector device, the authors are carrying out the corresponding calculations. For field experiments we are making bigger device with the collector area 2 m^2, which will be installed in a farm during the summer of 2006. The comparison of calculation and experimental results will prove the advantages of the invented (we have Latvia patent) device.

Conclusions

1. The results obtained by experimental mirror-collector device have been positive.
2. For more precisely examination it is necessary to produce bigger practically usable device and carry out experimental investigation for several years.

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