NEW INVESTIGATIONS IN SOLAR AIR HEATING COLLECTORS

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Abstract. The objective is to create and explore the easy-folding, disrupting, easily portable air heating solar collectors, which can be inflated and disassembled as many times as needed. The solar collector has to be constructively simple and cheap as well as simple and easy to transport. That could be an inflatable air heating solar collector. The inflatable base could be a good insulator on the one hand and absorbent on the other hand. We need to find out the air-heating collector efficiency. The study results confirm that the manufactured solar collector is sufficiently effective and easy to produce with small financial contributions. The average ambient air temperature increase in the experiments is 10.2 ºC and max increase is up to 16 ºC. This collector gives good correlation with the air heating degree and radiation ($r = 0.93$) and the efficiency coefficient of this collector is $\eta = 0.63$. Comparing the efficiency of the collector manufactured with another coating and the absorbent material collectors shows that the collector is manufactured for use in air heating.

Keywords: solar energy, air heating, inflatable collector.

Introduction

In recent years, increasing attention in the world is being paid to renewable energy resources in the economy, which have replaced the use of fossil fuels, which contribute to economics (oil, gas, coal prices) affecting the environment (the most common greenhouse gas emissions that cause greenhouse emergence), as well as safety (in 2011 the events in Japan, where the earthquake and tsunami caused nuclear disasters) factors.

The sun, that alternative energy source, more and more widely is used in national economics. The greatest advantage of solar energy as compared with other forms of energy is that it is clean and can be supplied without environmental pollution. So, if more people use solar energy to heat the air and water in their homes, our environment would be cleaner.

Solar air heating is a solar thermal technology in which the energy from the sun, solar insolation, is captured by an absorbing medium and used to heat air. Solar air heating is a renewable energy heating technology used to heat or condition air for buildings or processes of heat applications. It is typically the most cost-effective out of all the solar technologies, especially in commercial and industrial applications, and it addresses the largest usage of building energy in heating climates, which is space heating and industrial process heating.

Increase in the energy prices is an urgent problem in Latvia, so solar energy can be a good alternative to reduce the dependence on the fossil resources supplier countries.

We can use solar energy 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 more operations.

In general, solar air heaters are flat-plate collectors (FPCs), consisting of an absorber, a transparent cover, and backward insulation. The performance of solar air heaters is mainly influenced by the meteorological parameters (direct and diffuse radiation, ambient temperature and wind speed), design parameters (type of collector, collector materials) and flow parameters (air flow rate, mode of flow). The principal requirements of these designs are a large contact area between the absorbing surface and air [1].

The air heating collectors can be used in two main directions for product drying and room heating (ventilation). Product issues through drying in sun-warmed air are discussed in a lot of works [2; 3]. We are exploring a variety of coating and absorbent materials to increase the air warm-up stage.

There are different efficiency solar air heating collectors, it depends on the collector cover materials (polyvinylchloride film, cell polycarbonate PC, translucent roofing slate), absorber (black collared wood, steel-thin plate etc.) and insulation of the collector body with different air velocities in the collector; it was investigated in our works [4 – 8]. Mostly a lot of research is done for flat-plate solar collectors, these collectors are very big, we tried to create easy-to-use and easy for storage conditions, the collector that would take little space, and we had the idea of an inflatable collector. We like the idea of the inflatable solar air heating collector [9] so we made a prototype of our inflatable solar air heating collector and calculated its efficiency.

We want to look at and to study the created inflatable solar air heating collector (this type of collector is easy to dismantle and move) usage in product drying and room heating.

Currently in the world there are several companies which are producing solar panels commercially, you can purchase them, but in Latvia air collectors are not very popular. Mostly solar air heating collectors are fixed and are difficult to dismantle and move. We in the Latvia University of Agriculture have developed an inflatable solar air heating collector. The work has been focused at air-heating solar collector development to create easy to disassemble, compact, lightweight solar collectors, which if necessary can be quickly moved to another site and it does not require more than one person with a backpack. The inflatable solar air heating collector is also patented in Latvia [10].

Materials and methods

The solar collector had to be constructively simple and cheap as well as simple and easy to transport. That could be an inflatable air heating solar collector. The inflatable base could be a good insulator on the one hand and absorbent on the other hand.

The aim of the experiment was to make an inflatable solar collector. The inflatable solar collector had simple constructions, it was easily usable and transported. This type of collector is based on the inflated carcass with a good insulator of absorbent. As a coating material a polyethylene film was used. For the experiments we used an inflatable air heating solar collector with the dimensions: length 1.5 m, width 0.7 m and height 0.6 m (Fig. 1). We used a fan with the power 100 $m^3 \cdot h^{-1}$ for air ventilation in the collector.

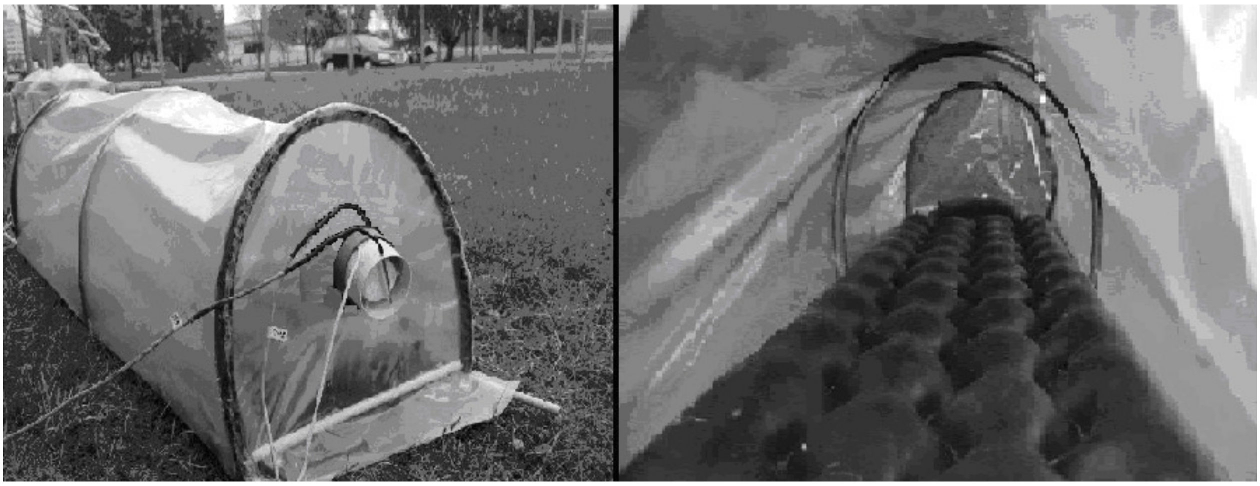

Fig. 1. **Inflatable air heating solar collector (overview, inside)**

For this aim an inflatable mattress painted black with spray paint can was used. The mattress has an uneven surface, and it is of different thickness at different points in the space, but it was considered as a plus, because it facilitates the flow of air at different temperatures in mixing. It was planned to set up an inflatable frame that enclosed the heated air from the environment. The collector was designed as a half cylinder shape to the surface coverage – polyethylene film. Following the surface coating solar air heating was investigated. It points to successful deployment of such coverage. The polyethylene film can be quickly and easily folded for transport, and the radiation transmittance was acceptable (89 %), so this seemed like an acceptable option.

The objective is to create and explore easy-folding, disrupting, easily portable air heating solar collectors, which can be inflated and disassembled as many times as needed.

To ensure air circulation in our collector we made a special hole which was inserted into the tube with the same diameter close to the diameter of the fan that provides air circulation (Fig. 2). In the experiments the POSPEL 16 W fan was chosen, which can move 100 cubic meters of air per hour.

Fig. 2. **Fan and its connection port**

The other end of the air-heating solar collector was partially closed with a polyethylene film to reduce heat losses from the collector. It was left as a slot for air supply manifold, which is a label area just above the fan diameter (Fig. 3). This was done to prevent the negative effects of wind on the collector performance.

Fig. 3. **Air inlet place**

The solar panel dimensions: length – 150cm, width – 70cm, height – 60 cm. The foundation also acts as an insulator, because it is filled with air, and we know that air has very good insulating properties, so the collector can be freely placed in any position on the earth to the sun.

The experimental data are recorded by means of the electronic metering and recording equipment of temperature, radiation and lighting REG [3]. The solar radiation measuring instrument was the pyranometer.

The experiments were made in 2011 from spring to the autumn in different weather conditions at different ambient air temperatures and wind speed.

Results and discussion

The data of the inflatable solar collector are shown in Figure 4. The experiment took place on May 6, 2011.

The results show a very strong correlation between the solar radiation and air warm-up stage. It should be noted that the air warm up in the collector quickly reacts to the changes in radiation (clouds, shadows). The response delay time of the inflatable collector is approximately 1 minute, compared to the classic it accounted for 5 – 7 minutes [4; 5].

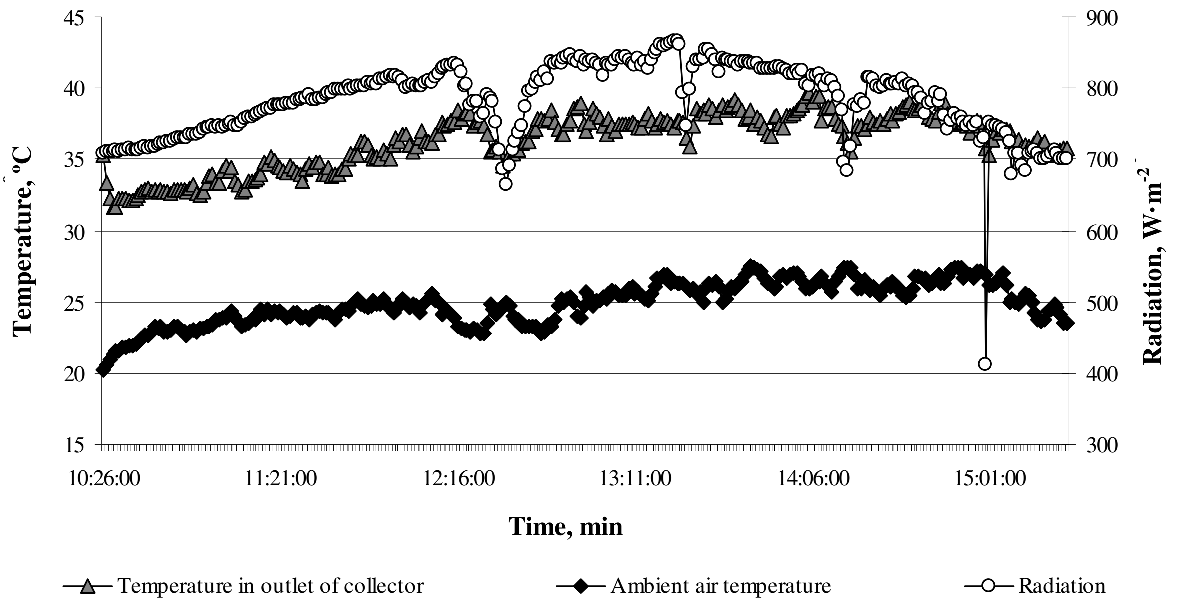

Fig. 4. **Inflatable solar collector heated and ambient air temperatures comparing with the sun irradiance in time**

Using the obtained data and taking into account the warm-up delay time (1 minute) the relationship is obtained, which is characterized by the atmospheric air warm-up degree in the inflatable air heating solar collector, depending on solar radiation (Fig. 5).

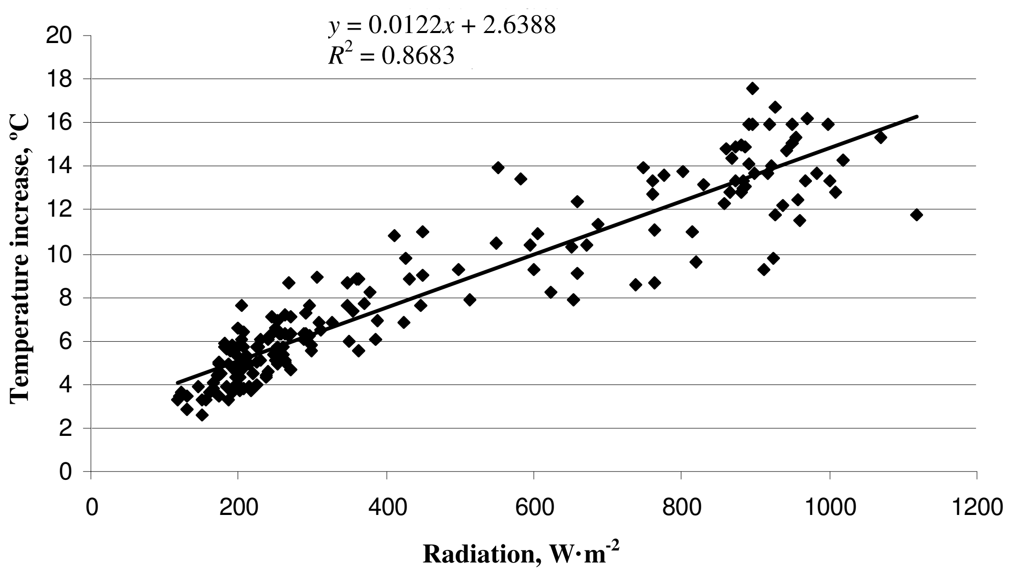

Fig. 5. **Temperature increase in outlet of inflatable air heating solar collector comparing with the sun radiation**

The high correlation coefficient ($r = 0.93$) should be noted with such rapidly changing sun radiation conditions. We determined the efficiency of the solar collector, as prescribed in the ASHRAE Standard 93 2003. The efficiency of the solar collector can be calculated by the following equation (1):

$$\eta = \frac{m \cdot c_p \cdot (T_{fo} - T_{fi})}{S \cdot R_T} \quad (1)$$

where η – efficiency coefficient of solar radiation converted into heat;
m – mass flow rate of air, $kg \cdot s^{-1}$;
c_p – specific heat, $J \cdot kg \cdot {}^{\circ}C^{-1}$;

S – area of solar collector, m^2;
R_T – global solar irradiance incident upon aperture plane of collector, W·m^{-2}
T_{fo}, T_{fi} – outlet and inlet working air temperatures, ºC.

With the equation (1) were defined the effectiveness coefficient over the all experimental time using average working air temperatures and radiation. In our case the inflatable air heating solar collector efficiency coefficient $\eta = 0.63$

Conclusions

1. Inflatable solar collector is giving good results, average ambient air temperature increase in the experiments is 10.2 ºC and max increase is up to 16 ºC. This collector gives good correlation with the air heating degree and radiation ($r = 0.93$).
2. This type of collectors is very sensitive to radiation changes; the response time is only about 1 minute. The given type of air heating solar collectors is of a good efficiency, the efficiency coefficient is $\eta = 0.63$.
3. The inflatable solar collector can be used for air heating in Latvian climatic conditions for room heating purposes at favorable weather conditions. The inflatable solar collector can be used as an extra heating device.
4. The inflatable solar air heating collector is easy to make, operate and rearrange the construction. It works well in Latvian climatic conditions especially if it is used in early spring, when ambient air temperatures are low.

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