The comparative material investigations of solar collector

J. Palabinskis, A. Aboltins, A. Lauva and N. Karpova-Sadigova

Latvia University of Agriculture, Liela iela 2, Jelgava, LV – 3001, Latvia;
e-mails: Janis.Palabinskis@llu.lv; Aivars.Aboltins@inbox.lv; Aigars.Lauva@inbox.lv; Nadezda.Karpova@llu.lv

Abstract. The prices of energy resources used for grain drying are increasing year by year. In order to reduce costs, research into methods of saving energy in grain drying is in progress in the Research Laboratory of Grain Drying and Storing of the Faculty of Engineering, the LUA. Equipment for experimental research into the materials of solar collectors was built in the research laboratory for research purposes in 2005. The construction of the equipment allows for simultaneous comparative studies of two materials. The experimental data are metered and recorded in the electronic equipment REG. Cell polycarbonate PC (bronze, henceforth referred to as polycarbonate) with absorbers steel-tinplate and black-coloured wood was researched in comparison to the polyvinylchloride film (henceforth referred to as a film). The researches were made with different air velocities. The air heating degree ΔT in the solar collector is dependent on solar radiation I and air velocity v in the solar collector. In the experimental equipment, which is 1.5 meters in length, the air was heated to $\Delta T = 6°C$ at the velocity v = 0.5 m s-1.

For theoretical investigation of the air heating power in solar systems the mathematical model is applied; the solution can be used for estimation of different materials /absorbents/ and their heat source.

Key words: radiation, sun, air, material, temperature, polycarbonate, film

INTRODUCTION

Grain drying including costs of its first treatment and storage depend upon equipment, the balance cost of buildings, power supply systems, the amount of the drying material and its moisture content, the level of cleanness and energy carrier's prices. All these costs are continuously rising.

Although fuel is getting more expensive, grain has to be dried before being stored. Increasing attention to environmental protection has resulted in exploration of the wider use of alternative energy. Among them, research into use of solar energy for grain drying is continually expanding. No man-made heat sources can compete with the sun, which annually emits 15000 times more solar energy than the entire global power industry can produce. Only a tiny portion of solar energy is being used for the sake of mankind.

Increase in the utilization of solar energy is closely connected with research into solar collectors. In Latvia, from July to September, at mid-day, the average solar radiation power on a horizontal surface is more than 600 W m-2 (Training Course, 1996), which, with active ventilation, is sufficient to dry grain. The air heated this way is not toxic and is electrically neutral. Solar collector efficiency is not high but it is simple to construct and is cheap to produce and operate.

MATERIALS AND METHODS

The aim of the research is to find the optimal technical solutions and materials, operation parameters and power possibilities for a solar collector. In the laboratory a 1.5- meter long experimental solar collector was constructed for research into the properties of roofing materials. The keystone of the experiment is to conduct comparative studies of the utilized materials for the solar collector. The building supply industry offers new materials whose applicability to solar collectors has not been studied. The collector has been built for ease of use in a laboratory setting. The box-like frame of the collector is divided into two parts (Fig. 1). One part is covered with a traditional material for solar collectors, i.e. a polyvinylchloride film, henceforth referred to as a film. The other part is used for the placement of the researched material, which is compared to the polyvinylchloride film. The two channels of the experimental equipment ensure equal experimental conditions.

The experimental data are recorded by means of an electronic metering device and equipment for recording of temperature, radiation and lighting REG (REG, 2004: 16 temperature transducers and metering sensors of solar radiation and lighting. The reading time of the data can be programmed from 1–99 minutes. The recorded data are stored in the REG memory (with room for 16.384 records) and if necessary, it is transferred to a computer for archiving with further processing. For evaluation and analysis of the results software REG – 01 has been developed, which is meant for transferring to the computer and processing of the recorded data. The information is stored in the form of a table and is depicted as a graph.

RESULTS AND DISCUSSIONS

In the experiment, the researched material was compared to the polyvinylchloride film, which in most cases is used as a solar collector material. Cell polycarbonate PC (bronze) (Plastikātu lokšņu …, 2008) was used as the researched material. This material has gained immense popularity due to such properties as safety, mechanical resistance, translucence and high UV radiation stability. It has easily bendable polycarbonate PC plates and they do not need previous treatment. As the experiments demonstrate, with high solar radiation I value the usefulness of the solar collector is essential for rising air temperature up to $\Delta T = 7°C$, which increases as the air movement velocity v decreases. There is no substantial difference in the outgoing air temperature T2 as well as the heating degree ΔT between the film and polycarbonate collectors. With solar radiation of $I < 100$ W m-2, the air heating degree does not exceed $\Delta T = 1°C$.

The research results of this material have been described (Lauva et al., 2006, Palabinskis et al., 2007). These results were obtained with absorber – black-coloured wood. The results of the investigations of the PC with absorber steel-tinplate are as follows (Figs 2 and 3):

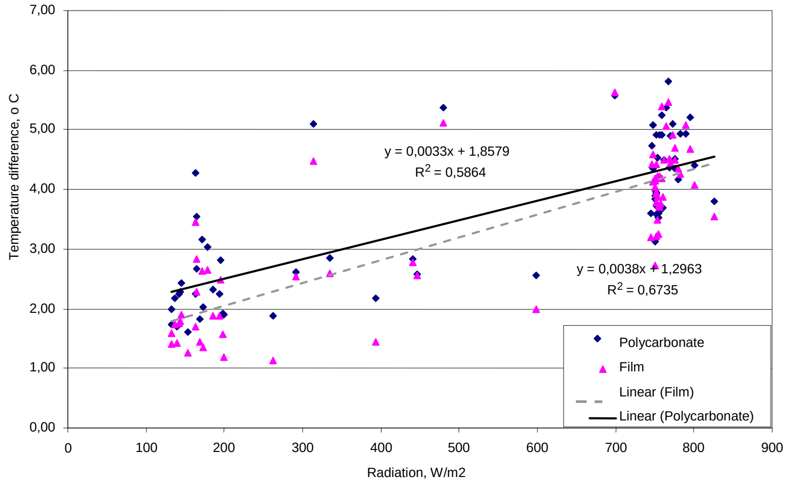

Fig. 1. Air heating temperature difference ΔT of film and polycarbonate with black-coloured wood absorber depending upon solar radiation I at air velocity v = 0.5 m s^{-1}.

The experiments show that absorber steel-tinplate works more effectively than black-coloured wood with polycarbonate plate cover of the collector (Figs 1 and 2).

As the experiments demonstrate, there is no important difference of temperature heating degree of the solar collector covered by polycarbonate and film (Fig. 2). The heating degree ΔT increases with growing radiation of sun.

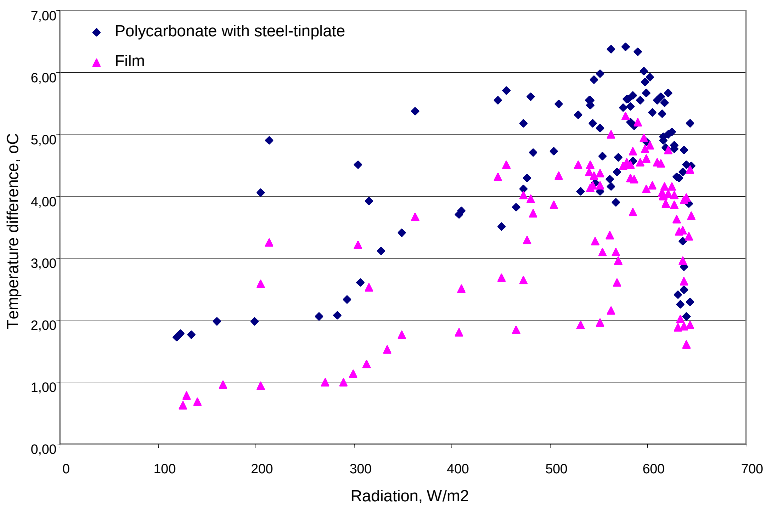

Fig. 2. Air heating temperature difference ΔT of film with black-coloured wood absorber and polycarbonate with steel-tinplate absorber depending upon solar radiation I at air velocity v = 0.5 m s^{-1}.

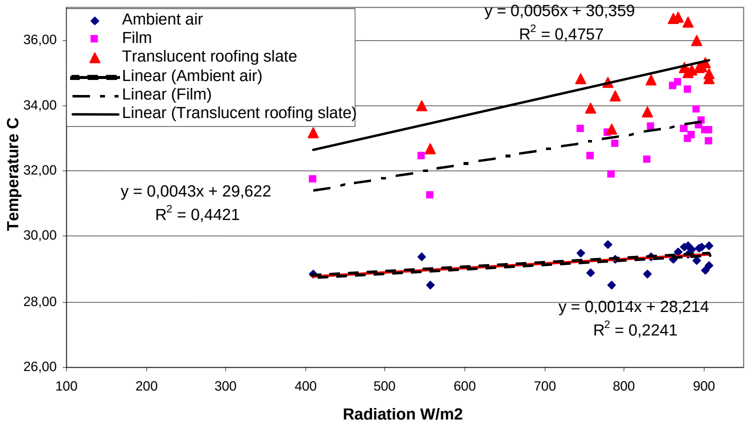

Fig. 3. Ambient air temperature, collector heating temperature covered by film and translucent roofing slate dependence from solar radiation I at air velocity v =0.75 m s^{-1}.

The researchers tried to find a correlation between the heated air temperature difference ΔT of the collector and two kinds of material – the polyvinylchloride film and the polycarbonate plate with different absorbers (Figs 2 and 3).

By comparing the effectiveness of usage, it is obvious that the air heating degree does not change substantially at low air velocities v and it is directly dependent upon solar radiation I volume. The heating degree ΔT (°C) is directly proportional to the radiation level I with sufficiently high correlation factors.

We compared temperatures of ambient air, temperatures of the end of the collector covered by film and translucent roofing slate depending of sun radiation with different air velocities (Figs 3 and 4).

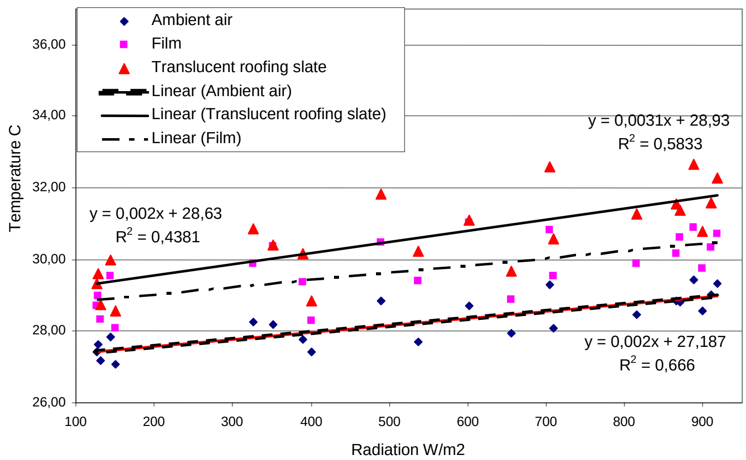

Fig. 4. Ambient air temperature, collector heating temperature covered by film and translucent roofing slate dependence on solar radiation I at air velocity v = 1.34 m s^{-1}.

It can be seen that the effectiveness of translucent roofing slate is higher than that of the film. Small velocities have higher effectiveness than large velocities. The correlation of dependents (from experimental data) is high $r \in (0.65; 0.85)$. At lower air velocities $v = 0.75;\ 0.95$ m s^{-1} the correlation is lower. The experimental results show that heating degree of the solar collector depending on the air velocity is higher with lower velocities.

Mathematical modelling of the solar collector using the programme package ANSYS (Figs 5 and 6) was also started.

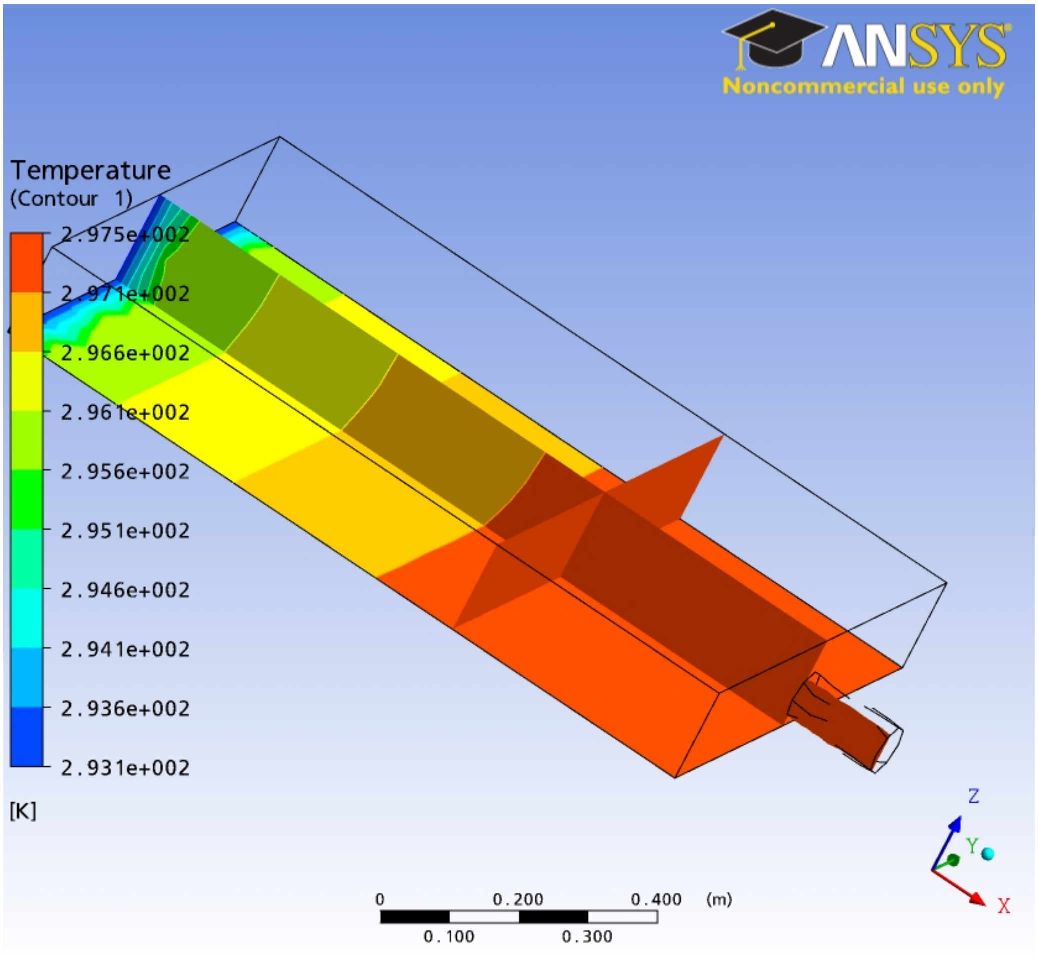

Fig. 5. Air heating degree in solar collector.

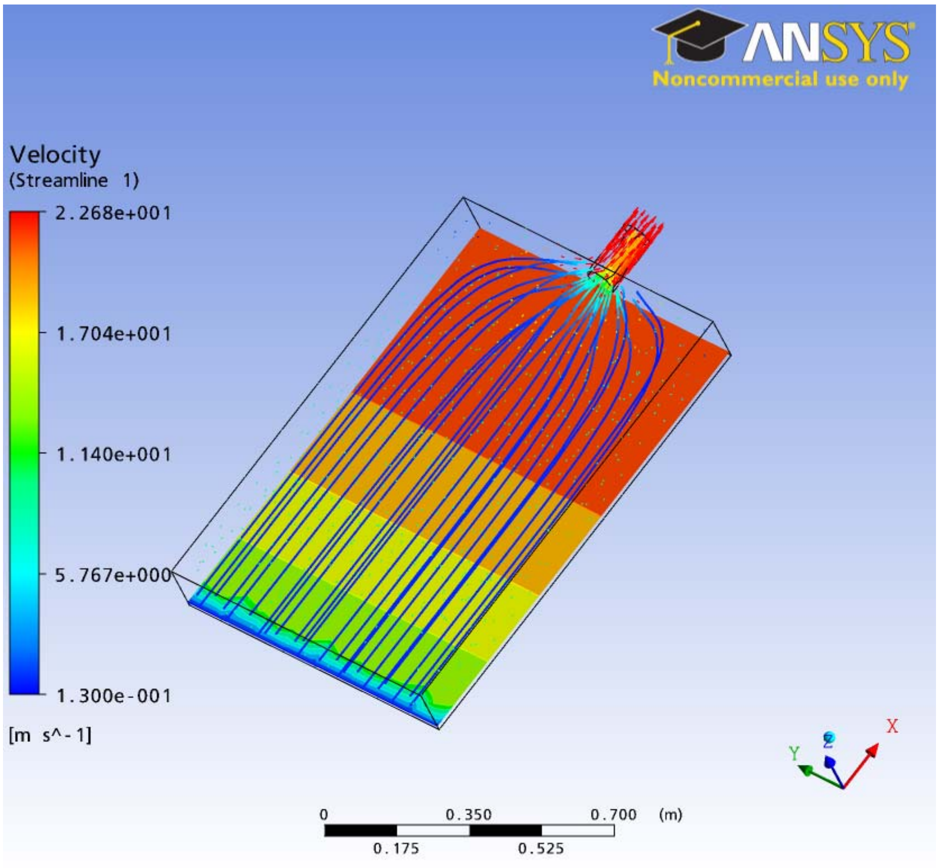

Fig. 6. Air velocity streamlines in solar collector.

For future investigations we made a one-man movable solar collector (Figs 7 and 8).

Fig. 7.

Fig. 8.

Movable solar collector.

CONCLUSIONS

1. The air heating degree ΔT in the solar collector is dependent on the solar radiation I and the air velocity v in the solar collector. In the experimental equipment, the length of which is 1.5 meters, the air heated to $\Delta T = 6°C$ at the velocity $v = 0.5$ m s^{-1};
2. The air heating degree ΔT in the polycarbonate collector did not significantly differ from the film collector using black-coloured wood absorbent, but it is significantly higher using absorbers of steel-tinplate;
3. The translucent roofing slate is more effective as a sun collector material than the polyvinylchloride film;
4. The research results demonstrate a close correlation between the air heating degree ΔT and the solar radiation I at various velocities of air v in the collector;
5. Polycarbonate PC and translucent roofing slate, due to their physical and mechanical properties, are suitable materials to be used in solar collector construction for agricultural purposes.

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