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EXAMINATION OF THE THERMAL EFFICIENCY OF THE SOLAR COLLECTOR INTEGRATED INTO THE LIGHT TRANSPARENT BUILDING FACADE

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The work describes the prospects for the development of solar energy in Ukraine. Interest in the effective use of solar radiation by solar collectors justifies the relevance and expediency of research on the problem of using such energy in them. It is analyzed that solar energy remains a promising direction for generating thermal energy due to: the increased volume of solar radiation entering the territory of Ukraine and the wear or tear of technological equipment running on traditional organic fuel. Also, if taking into account the trend of building glass facades in the field of construction, in the work proposed solar collector which was integrated into the light transparent facade of the building. The solar collector model was developed for the purpose of in order to save space where solar collectors should be installed and to save fossil fuels. The temperature at the outlet of the solar collector reached 22.9 °C according to the intensity of the simulated solar radiation of 900 W/m^2, which fell on the absorbing surface of the solar collector. Comparing the changes in the instantaneous power of the solar collector Q_{SC}, W/m^2, it was found that at 60 minutes of the experiment was greater than 250 W/m^2 under the intensity of the simulated solar radiation of 900 W/m^2. The efficiency of the experimental solar collector reached ≈33% in the direct heat carrier mode in the system according to the intensity of the simulated solar radiation. It was established, that the proposed solar collector in the mode of direct heat carrier was the effective source of low potential heat supply under intensities which could correspond to the power of solar radiation at summer time of the year. The promising direction for further research will be the efficiency establishing of the collector under simulated intensities of the solar radiation and other modes of operation of the heat carrier.

Key words: solar radiation, solar collector, light transparent facade

Introduction

The introduction of energy-resource savings technologies is an urgent issue in the field of energy. As a rule, energy-saving installations have a high efficiency as opposed to conventional technological installations due to improved materials that are used in them or the organization of their work. For example, energy-saving installations could using a repeated resource in their technological scheme or they could use energy sources that are renewable. In the future, such installations may take the place to be not only priority in use, but also necessary. Since the greater energy situation complication in the world which are primarily due to the limited reserves of traditional organic fuel, the difficulties of using nuclear energy and the problems of environmental pollution. As a result, the reuse of energy from resources removed from energy-intensive industries or the use of renewable energy sources (solar, wind, geothermal, etc.) are becoming increasingly popular and are the relevant research area. (Zolotko, 1998, Mysak, 2014)

On the other hand, one of the most important problems facing modern society is the need for a large amount of energy supply. Worn-out power plants in Ukraine can not provide this amount of energy. Therefore, alternative (renewable) energy, in particular solar, is the priority solution in solving this problem. So, solar energy can provide the necessary amount of electrical or thermal energy, which is now no longer able to provide outdated installations. This solution will reduce the share of traditional energy carriers in the overall energy balance. In addition, it will create new jobs for the production and maintenance of solar installations. Despite the fact that the solar energy is the almost inexhaustible and environmentally friendly source. (Kutnyi, 2014)

The total output power of the Sun is $3.8\text{x}10^{23}$ MW, of which 1.7×10^{14} kW comes to the Earth's surface. If this amount of energy which was received on the Earth's surface within 30 minutes could be used, then this amount of energy will be able to meet the world's annual total energy demand. Solar energy is widely available worldwide, but it is only a small fraction of the energy used by solar collectors compared to traditional energy (oil, coal, or natural gas) that is used in conventional process plants. (Salvi, 2018)

A solar heat collector is a special type of heat exchanger that absorbs incident radiation, converts it into heat, and then transfers the heat of the working fluid (water, oil, gas, etc.) by conduction and convection. Solar thermal collectors are mainly classified by the ability to track the Sun and the mode of operation. Solar collectors that do not follow the Sun (stationary) have the same area of capture of solar radiation and its absorption. These designs are sufficient for low-temperature applications with water/air heating to a temperature of ≈ 90 ºC. In addition, these designs are advantageous with a feasibility study for the average consumer compared to high-temperature solar collectors. However, in economic terms the situation is the opposite for the vast majority of industrial enterprises. (Salvi, 2018, Vozniak, 2014)

Available on the market and technically easy to use are flat solar collectors the design of which usually consists of the element that absorbs solar radiation (the active part of the solar collector), a transparent coating and a thermal insulation layer. (Kutnyi, 2014)

A separate area of research is the use of carbon graphite materials as the solar energy absorber for solar collectors. The thermal characteristics of the absorber do not deteriorate for using this type of fabric. In addition, it is possible to introduce solar heat supply systems based on such combined collectors in the industries, construction, and agro-industrial complex. (Pasichnyk, 2013) The paper (Syvoraksha, 2001) describes analytical formulas for the dependence of design parameters that affect the use of solar energy in a tubular-ribbed solar collector. (Syvoraksha, 2001) This approach helps to detail the design and select the necessary design features of the solar collector for practical implementation.

Cost-effective solar collector designs using polymer material that have a longer service life due to the use of polymer material in their design solution. (Zhelykh, 2013)

No less important is the direction of research to establish the thermal parameters of the absorber or solar collector as a whole using computer modeling. (Shapoval, 2020)

In the world, the study of solar collector dynamic modeling in the system is becoming popular. The paper (Filipowicz, 2019) demonstrates the results of daily and weekly operation of the system with the solar collector by its dynamic modeling with data integration for the selected time period (week). In addition, if analyzing the sensitivity of the solar collector to the perception of solar radiation, also analyzed the influence of the concentrator area on the energy generation index of the system. (Filipowicz, 2019)

As the rule, solar collector designs require considerable space to place the collectors themselves on the Earth's surface.

Problem statement

The amount of solar radiation energy received and its share in the total fuel and energy complex of Ukraine encourages the development or improvement of structures that use solar energy as opposed to traditional organic fuel installations. Interest in the effective use of solar radiation by collectors justifies the relevance and expediency of research on the problem of using such energy in them. In parallel with improving the design of the solar collector, it is necessary to look for alternative solutions to preserve the useful surface area of the Earth that is necessary for their installation.

Analysis of recent research and publications

Popular on the market are solar collectors containing foclin-type concentrators. Such installations are compact, have a low cost and do not require daily tracking systems for the Sun, which makes them convenient to operate. (Khotin, 2001).

Modern research is described by Italian scientists (Buonomano, 2018) demonstrate the solar collector dynamic model based on codes written in the MatLab software. These codes allow us to study the energy, economic and environmental performance of new solar polygeneration systems founded on both adsorption/absorption technologies of the refrigeration unit. In addition, they are written for concentric and flat-shaped photovoltaic/thermal collectors. This model allow to optimize the calculation of the solar collector.

Scientists from the Fraunhofer Institute for Solar Energy Systems ISE, that in Germany, together with co-authors from Spain and Ireland, they claim that with few studies of systems BIST (Building-Integrated Solar Thermal Systems) most researches related to configurations with photovoltaic solar collectors. It is noted, that there is a need to study the BIST installations themselves, but with an active configuration, that is, with those that can provide thermal energy for the needs of energy consumption. Taking into account previous studies where simulations of the BIST focus on the system itself, the authors (Lamnatou, 2015) give conclusions about the necessary additional studies that study the system in conjunction with the building. (Lamnatou, 2015)

At a number of works, demonstrates the technology of combining the building's coating with the solar collector design (Shapoval, 2017). However, paying attention to the trend of building glass facades in the world, it is necessary to consider the possibility of introducing the solar collector into the light transparent facade of the building.

Considering the economic component of such structures, it can be argued that the conversion of solar radiation requires a high-cost energy system in order to provide the necessary heat/electricity needs for the consumer. The cheapest system with the solar collector must be able to transmit and store energy in order to provide sufficient power. Taking into account the advantages of solar energy, the development of such structures should be encouraged at the state level through the introduction of legal framework and legislation. Because it will help open new approaches to the development of a cost-effective energy supply system for the use of solar energy, which is an unlimited resource.

Highlighting previously unsolved parts of the common problem

It is worth noting that most of the scientists in their works focus on improving the solar collector design or system with its content. However, the issue of improving the thermal efficiency of the solar collector and saving the useful surface area occupied by solar collectors are given little attention conceptually.

Purpose of research

Given the above, for the territory of Ukraine, which has sufficient potential for solar energy (Venhryn, 2019), the promising direction for the construction and architecture industry development is the use of solar collectors combined with architectural designs of energy-efficient buildings, that is, integrated into the building. It was proposed to determine the thermal efficiency of the solar collector integrated into the light transparent facade (SCI into LTF) in order to save surface area occupied by solar collectors and trends in the construction of translucent building facades in the world.

The main material

For research, it was developed SCI into LTF (Fig. 1). The experimental solar collector consisted of a frame housing 1 that included the light transparent coating (for this case, a glass coating) in the middle of which transparent tubes 2 were placed for the heating circuit of the carrier heat in it. The heat carrier was supplied to the solar collector through the main inlet pipe 3 and the intake to the heat supply system was supplied through the branch pipe 4.

During the experimental studies, a continuous movement of the heat carrier with the constant flow rate through the developed structure took place SCI into LTF, that is, the system worked in the direct heat transfer mode.

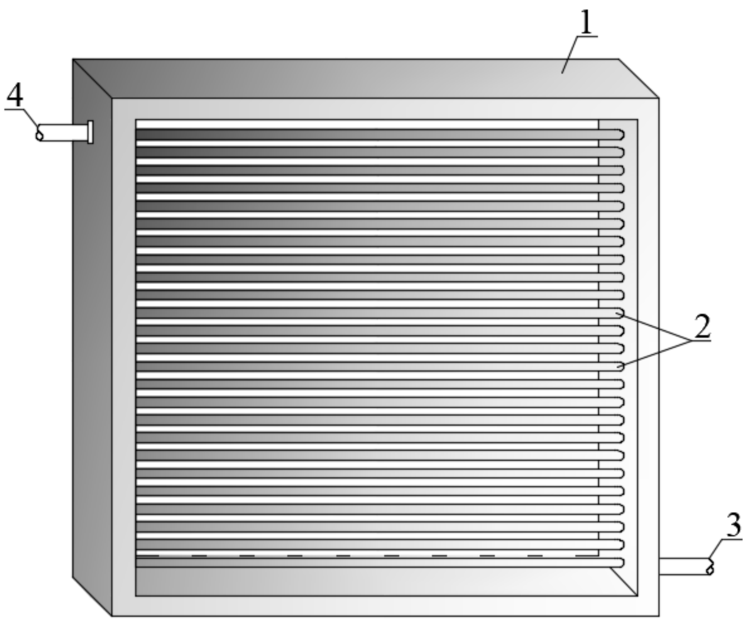

Fig. 1. The schematic design of the investigated solar collector integrated into the light transparent facade of the building, where 1 – the frame housing, 2 – transparent tubes of the heating circuit of the heat carrier, 3 – the main pipe for supplying cold heat carrier to the solar collector, 4 – the main pipe for collecting heated heat carrier

The main parameter responsible for the state of the thermodynamic system in the design of the solar collector is its heat carrier temperature. Therefore, according to studies of thermal characteristics SCI into LTF in the direct heat carrier mode the temperature change of the heat carrier at the inlet and outlet of the solar collector structure was analyzed in detail.

According to the intensity of the simulated solar radiation of 900 W/m^2, which was caught on the active surface of the solar collector, the temperature at the exit from the solar collector was greater by ≈26 % than at the entrance from it during the experiment (Fig. 2).

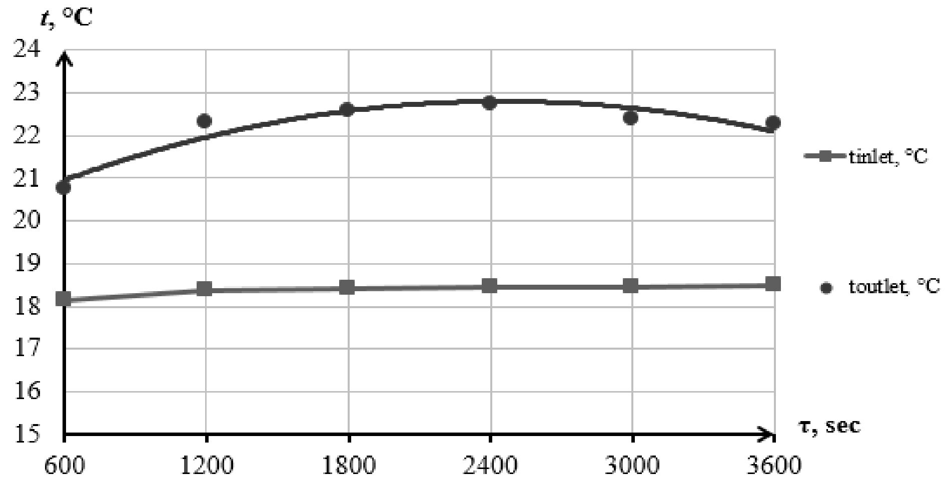

Fig. 2. The change of the temperature of the heat carrier at the inlet t_{inlet}, ºC and outlet t_{outlet}, ºC of the solar collector during the experiment

An important thermal engineering parameter that characterizes the design of the solar collector is the amount of instantaneous power generated by the design. If comparing changes in the instantaneous power of the solar collector Q_{SC}, W/m^2 it was investigated that for 60 minutes of the experiment, instantaneous power was more than 250 W/m^2 under the intensity of simulated solar radiation 900 W/m^2 (Fig. 3).

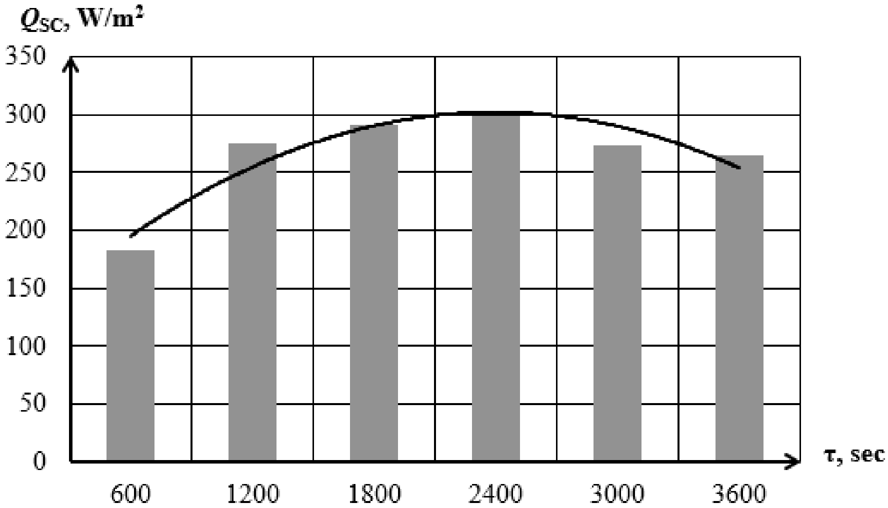

Fig. 3. The change of the solar collector instantaneous power Q_{SC}, W/m^2 during the experiment

Efficiency SCI into LTF was determined by the formula:

$$\eta_{SC} = \frac{Q_{SC}}{I} \cdot 100\ \% \qquad (1)$$

where Q_{SC} – specific instantaneous heat output SCI into LTF, W/m^2; I – the intensity of simulated solar radiation received on the active surface of the solar collector, W/m^2.

It was determined that the efficiency of the experimental solar collector in the mode of direct heat carrier in the system reached ≈33 % under the intensity of simulated solar radiation 900 W/m^2 (Fig. 4).

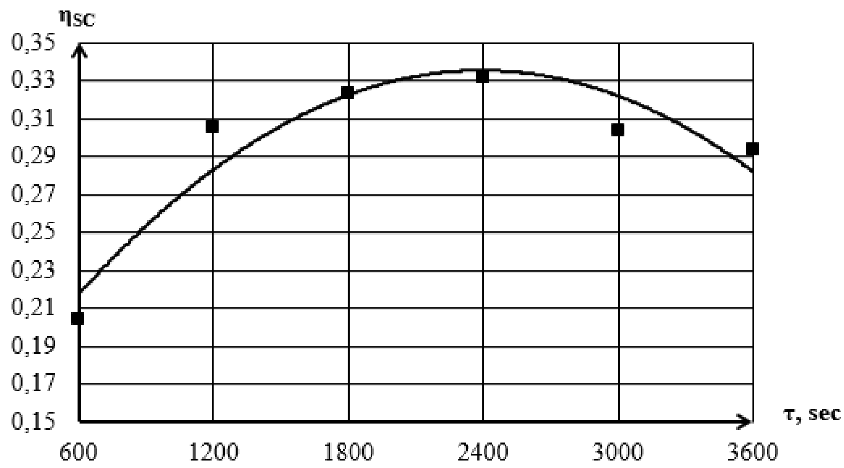

Fig. 4. The change in thermal efficiency η_{SC}
of the studied solar collector during the experiment

Based on the analysis of the above graphical dependencies, it can be argued that the proposed SCI into LTF, for intensities corresponding to the power of solar radiation at lunchtime during the summer period of the year, in the mode of direct heat carrier through SCI into LTF it is an effective source of low-potential heat supply.

Conclusion

Given the growing trend in the number of buildings with glass facades, a promising direction in the field of solar heat supply is the integration of solar collectors into such facades of buildings, which will allow obtaining a preheated heat carrier for its subsequent use in the solar heat supply system. The feature of the proposed solar collector integrated into the light transparent facade of the building is the ability to effectively use the area of the building's external fences, due to its integration into the design of the glass facade of the building. In addition, it was found that at the intensity of solar radiation 900 W/m^2 the developed solar collector can generate instantaneous thermal power of about 250 W/m^2. It was determined that the average coefficient of thermal efficiency of the solar collector was 0.29 in the direct heat carrier mode in the solar heat supply system, which made it possible to assert the feasibility of using such solar collectors integrated into the light transparent facade of the building.

Setting the thermal efficiency of the developed solar collector due to changes in the intensity of simulated solar radiation and different modes of movement of the heat carrier through the heat exchanger of the solar collector in the solar heat supply system remains the promising area for further research.

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ВИЗНАЧЕННЯ ТЕПЛОВОЇ ЕФЕКТИВНОСТІ СОНЯЧНОГО КОЛЕКТОРА ІНТЕГРОВАНОГО В СВІТЛОПРОЗОРИЙ ФАСАД БУДІВЛІ

Описано перспективність розвитку напрямку сонячної енергетики в Україні. Інтерес до ефективного використання сонячного випромінювання сонячними колекторами обґрунтовує актуальність і доцільність досліджень з проблеми використання в них такої енергії. Проаналізовано, що сонячна енергетика залишається найперспективнішим напрямком для генерації теплової енергії внаслідок: встановленого обсягу надходження сонячного випромінювання на територію України та зношеність технологічного обладнання, що працюють на традиційному органічному паливі. Окрім цього, враховуючи тенденцію побудови скляних фасадів у галузі будівництва, в праці запропонованого сонячний колектор інтегрований в світлопрозорий фасад будівлі з метою економії площі, на яку встановлюються установки сонячних колекторів та

збереження викопних видів палива. За інтенсивності імітованого сонячного випромінювання 900 Вт/м^2, що потрапляло на поглинаючу поверхню сонячного колектора, температура на виході із сонячного колектора досягала 22,9 ºС. Порівнюючи зміни миттєвої потужності сонячного колектора $Q_{ск}$, Вт/м^2 встановлено, що на 60 хв експерименту за інтенсивності імітованого сонячного випромінювання 900 Вт/м^2, вона була більшою за 250 Вт/м^2. Коефіцієнт корисної дії експериментального сонячного колектора в режимі прямотечії теплоносія в системі за інтенсивності імітованого сонячного випромінювання 900 Вт/м^2 досягав ≈33 %. Встановлено, що запропонований сонячний колектор за інтенсивностей, що відповідатимуть потужності сонячного випромінювання в літній період року, в режимі прямотечії теплоносія через конструкцію соячного колектора є ефективним джерелом низькопотенційного теплопостачання. Перспективним напрямом подальших досліджень залишається встановлення ефективності такого колектора за інших інтенсивностей імітованого сонячного випромінювання та за інших режимів роботи теплоносія через конструкцію сонячного колектора в системі сонячного теплопостачання.

Ключові слова: сонячне випромінювання,сонячний колектор, світлопрозорий фасад