Simulation of Thermal Processes in the Solar Collector Which Is Combined with External Fence of an Energy Efficient House

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Abstract. Efficient and rational use of energy carriers is one of the important issues of energy policy of the EU and Ukraine. In this regard, it is important to design systems that will be based on the use of renewable or inexhaustible energy for efficient and rational use of the fuel and energy complex of Ukraine at the international level and heat supply of houses at local levels. This solution can be achieved by using solar systems to generate electricity and heat. In general, territory of Ukraine belongs to the average zone with solar radiation intensity. The value of annual solar radiation per 1 m^2 on the earth's surface has a static distribution. The work considers energy efficient solar system combined with external fence of energy-efficient building. The paper describes the data of functioning mechanism of the solar collector using mathematical modeling. The article analyzes the heat technical characteristics of the proposed solar collector for the possibility of their subsequent installation and application by consumers.

Keywords: Computer simulation · Solar fence · Solar roof · Heat carrier · Efficiency · Energy-efficient building

1 Introduction

Alternative fuels are becoming more important than other fuels. For example, the main advantage of solar energy over conventional fuels are the inexhaustibility of this energy source. As well as the possibility of using solar energy in almost all areas of the earth's surface. Such alternative energy source is environmentally friendly but geographically differentiated.

In general, Ukraine territory belongs to the zone with average solar radiation intensity. The annual amount receipt of solar radiation per 1 m^2 on the earth's surface has a static distribution pattern and changing throughout all territory of Ukraine.

It is known that only about 3% of the solar flux which falls on the earth's surface could be used from the total solar energy from cosmos without damage on the

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biosphere. This is 1000 billion kW of energy in terms of mankind needs. This capacity is 100 times higher than the current capacity of energy production on the planet.

Improving energy efficiency in buildings is the one of the most cost-effective ways in all sectors for reducing energy consumption and reduce greenhouse gas emissions as the consequence. Certification and additional measures can solve these problems (International Energy Agency 2010).

In 2008 the number of passive houses were ranged from 15 000 to 20 000 units worldwide. The vast majority of them were built in German-speaking countries and Scandinavia. The first certified passive house in the Antwerp region from Belgium was built in 2010. In 2011 the government of Heidelberg in Germany initiated the Bahnstadt project which was marked as the world's largest passive house. The company in Qatar established the first passive house in the country in 2013 (Kaklauskas 2015).

In the computer industry with regard to heat supply systems the TRNSYS 17 software is used to evaluate the efficiency of several designs of hybrid systems. Such hybrid systems which are consisting of solar thermal collectors, photovoltaic panels and natural gas combustion engines. Studies are conducted in Spain in five different places with different climatic characteristics. Moreover, there is analyzing the behavior of the designed systems for the one house in all five cases (Rodríguez et al. 2016).

A promising solution in Smart Energy Networks (SEN) is to combine renewable energy sources with cogeneration systems that are highly efficient. This, in turn, can help to integrate alternative technologies in widespread use (Mathiesen et al. 2015; Sig Chai et al. 2013; Lund et al. 2012).

2 Objectives the Formulation of the Problem

On the one hand, promising development direction of the construction industry and architecture is use of combined solar heating systems with the purpose to solve set tasks which are exist before Ukraine in area to improve the energy and environmental situation. On the other hand, such systems are based on solar collectors combined with architectural constructions of energy-efficient buildings (Shapoval 2019).

In connection with the above, modeling of thermal processes in solar collectors combined with an external fence of an energy-efficient house is an important study for further large-scale introduction of solar collectors by consumers.

Therefore, the purpose of this work was to simulate external solar fences for the house with taking into account using the useful area of energy-efficient facade and the implementation such fences experimentally in the future.

3 The Analysis of Recent Research and Publications

Exploitation of solar energy in construction is described in (Chwieduk 2014). In addition, the work contains the scientific basis for the use of solar energy and practical recommendations to this.

In particular, a number of studies are described in (Yudong 2012) and there was dedicated to green buildings. However, this thesis focused on the management of

microclimate systems and the result forecasting of their work. On the basis of this work was developed the predictive control model (MPC). Such model was as a unified management methodology that could be systematized and take into account future projections during the design phase while adhering to system constraints.

Studies of the use of solar energy was engaged by Shchukyna (2011), which offered scientific and methodical approaches to search of ways to increase the efficiency of passive/active solar systems for achievement of the maximum possible power supply in buildings.

Scientists have developed recommendations for system analysis and modeling of active/passive methods of radiation capture with using absorbing materials. The system analysis includes thermal insulation materials and materials for the screening of solar protection devices under unstable weather conditions and according to seasonal changes in loads. Studies confirm the prospects of alternative energy supply studies through the use of flat collectors with corrugated translucent protection for houses of only a certain type. However, there is no comprehensive approach to the energy supply of passive houses.

In modern studies, particularly in Italy (Buonomano et al. 2018) has been developed the dynamic model of the simulations codes which are written in MatLab. This model allowed to investigate the energy, economic and environmental performance of new solar systems pageneral. This is based on adsorbing or absorption technology chillers, which are served in concentrated or flat photovoltaic/thermal collector.

Christoph Maurer of the Fraunhofer Institute of Solar Energy from Germany with co-authors from Spain, Ireland argue that with few system studies BIST (building-integrated solar thermal systems), most studies related to the BI configurations, namely PVT, PV. Thus, there is a need for additional research related to BIST installations, especially for active configurations that can provide thermal (or electrical/thermal) energy for energy consumption needs. Taking into account previous studies where BIST modeling focuses on the system itself authors draw conclusions about the necessary additional studies of the system in conjunction with the building (Lamnatou 2015).

4 The Main Material

In the current conditions, it is necessary to perform a preliminary computer analysis of solar heating systems, since in real conditions it is difficult to explore in details more factors affecting their operation.

To determine the feasibility of exploitation solar collectors integrated with the external fencing of the building it is necessary to conduct a preliminary simulation. Figure 1 shows a house containing a solar roof, a solar wall and a solar window. To determine the effectiveness of the solar wall, solar window and solar roof, it is advisable to consider these elements separately and simulate their work with the help of

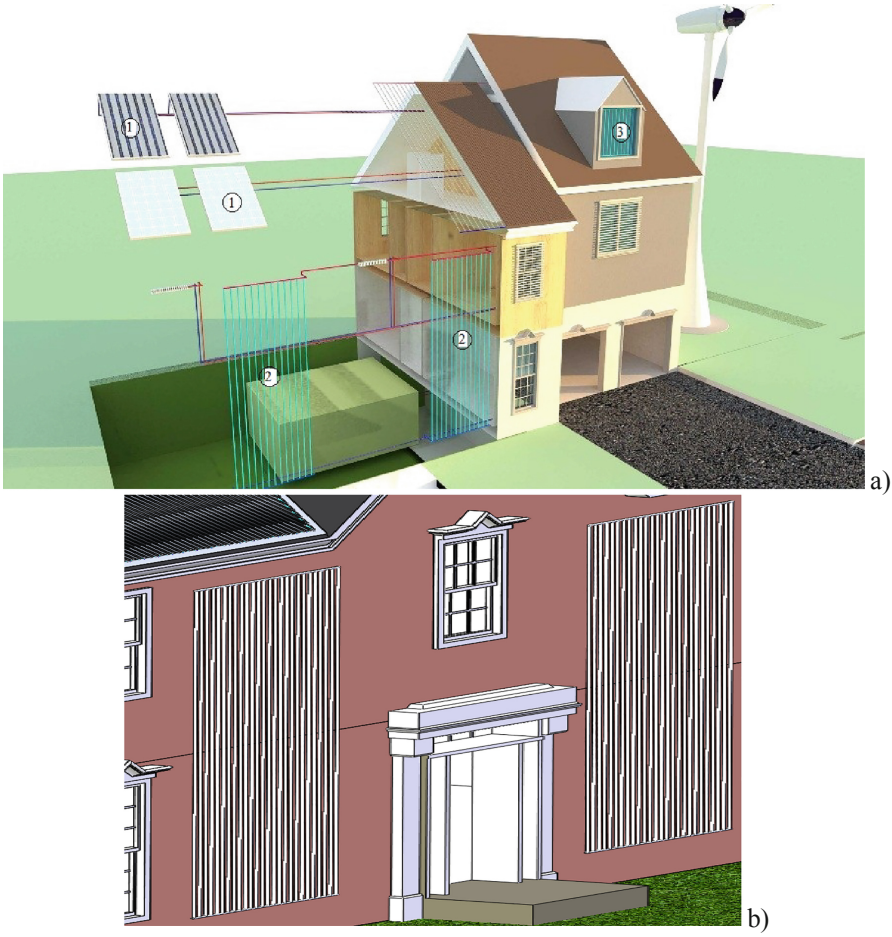

Fig. 1. Model (a) energy-efficient building where the solar roof (1), solar wall (2), solar window (3) and (b) enlarged image of the solar wall in the SolidWorks software

computer technology, in particular in the SolidWorks program. In all studies, the physical parameters of water were taken as a heat carrier.

In the article was considered the modeling of the solar wall and roof as a solar collector. Figure 2 shows a computer model of the solar wall, and Fig. 3 - the solar roof. With this design, the solar collector is structurally combined with the wall of the house or with the roof. It is carried out for the purpose of useful use of the protections area of the building.

Figure 4 shows the model of the solar wall where the heat carrier is heated by programmed solar radiation.

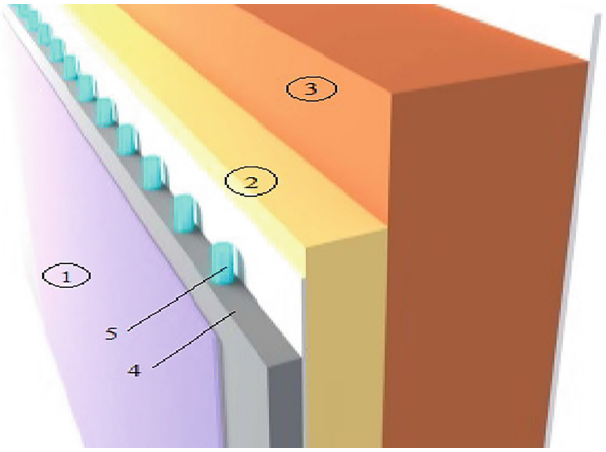

Fig. 2. Model of the solar wall, where 1 – light transparent fencing, 2 – thermal insulation, 3 - load-bearing wall design, 4 – screed, 5 – tube circuit circulation

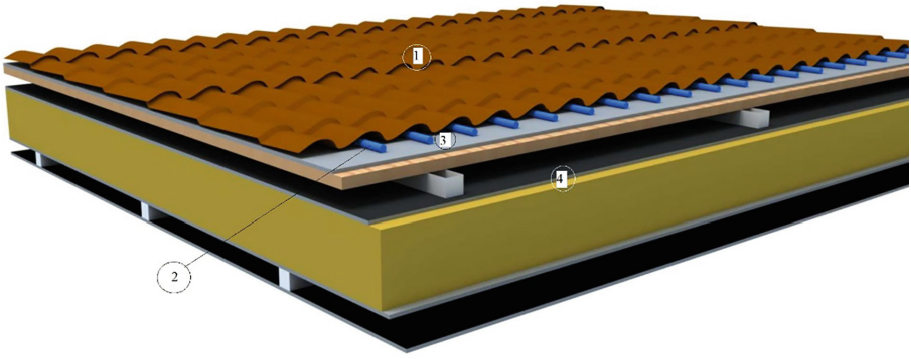

Fig. 3. Model of the solar roof 1- profiled decking, 2 – tube circuit circulation, 3 – thermal insulation; 4 – supporting structure of the roof

The angle of the solar wall installation was taken into account in the program code since it is a vertical structure. In Fig. 4, the solar wall is drawn from this angle in order to better illustrate the heat carrier movement to the storage tank.

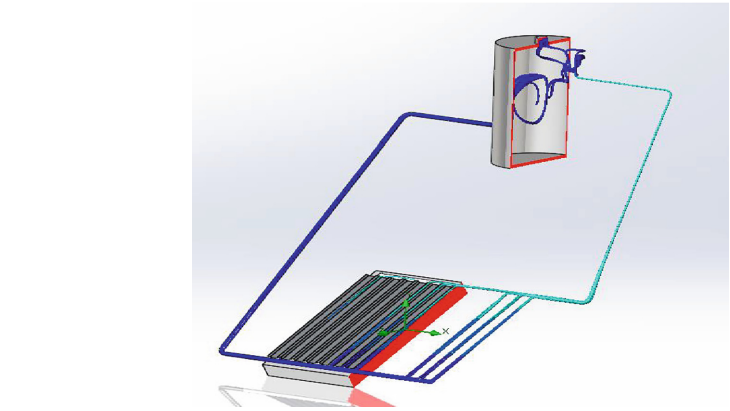

Fig. 4. The heat carrier heating due to pre-programmed solar radiation in the solar wall model

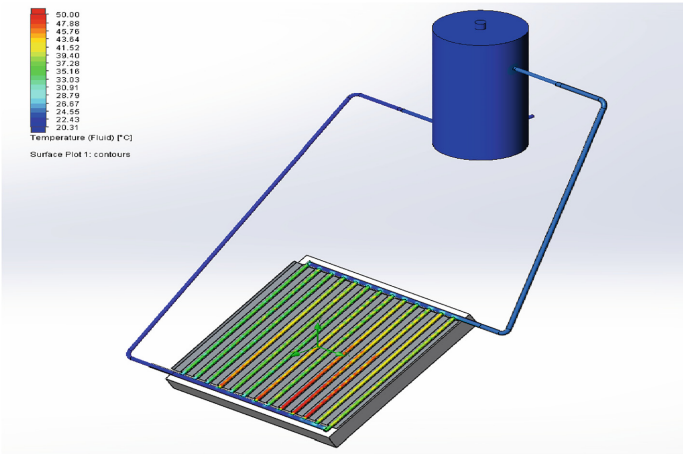

Fig. 5. Model of the solar roof

The solar roof is shown in Fig. 5, where the heat carrier is heated under the heat absorber (under profiled decking) due to the gravitational motion of the heat carrier in the solar heat supply system. The maximum temperature reached in this computer model was amounted 50 °C.

The result of the heat supply system simulation of the energy-efficient home with solar fences is shown in Fig. 6.

The average coefficient of efficiency (CoE) are obtained on the basis of the computer simulation of solar fences separately and in the solar heating system.

As a result of the simulation of the accumulation of solar radiation by the solar roof and the solar wall it was found that the CoE of the solar wall reached 0.65 and the solar roof – 0.69 (Fig. 7). Such data shows about efficiency and prospects of application of these designs.

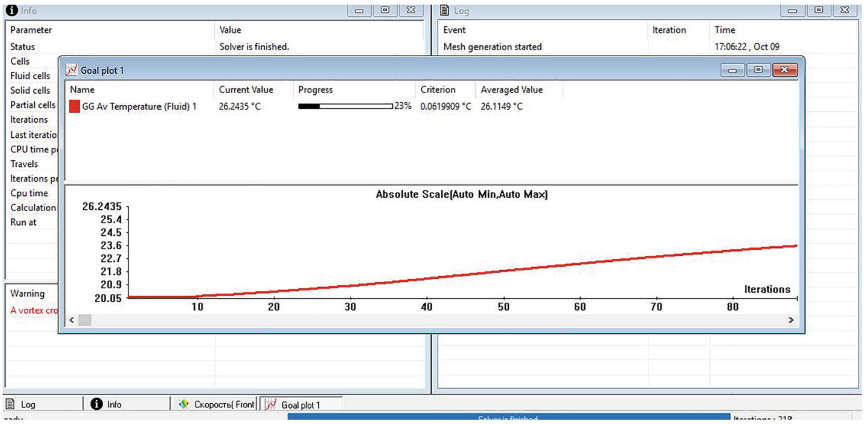

Fig. 6. Modeling of the heat carrier heating in the storage tank when simultaneous operation of solar fences

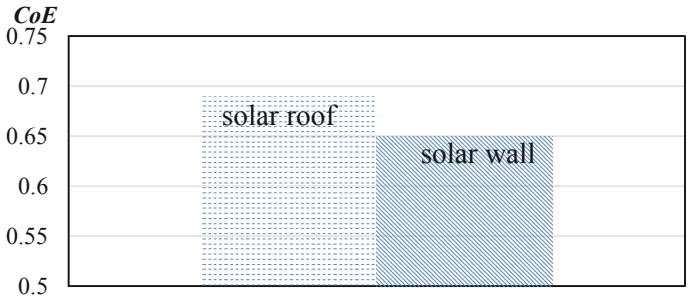

Fig. 7. The average coefficient of efficiency for solar fances

5 Conclusions

Modeling of the processes work in structures for their subsequent application in practice is the important step for the development and preliminary improvement before using by consumers. Computer simulation in the software Solidworks has improved the design of combined solar wall or roof of the building. Software simulation is carried out for these circuit solutions allows for engineers to place the solar structure correctly on the facade of the energy-efficient house and choose cost-effective materials for the construction of such fence by the consumer. The efficiency calculated by the software was 69% for the solar roof and 65% for the solar wall.

In light of further research, it is planned to improve computer models and operations of the solar roof and wall.

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