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INFLUENCE OF ORIENTATION ON EFFICIENCY OF COMBINED SOLAR HEATING SYSTEM IN GRAVITY MODE

The use of renewable energy sources is a priority and a qualitative new direction in the energy sector. The article presents the efficiency of heat generation in a heating system with solar collectors at different orientations relative to the horizon. Graphs illustrating the temperature changes in the proposed solar heating system and the amount of solar radiation energy falling on the solar collector during the experiment are presented. In addition, the amount and efficiency of heat generation in the examined collector system was determined.

Keywords: **solar collector, gravity mode, combined solar heating system, intensity of solar radiation energy on solar collector surface, specific thermal energy, energy efficiency**

INTRODUCTION

One of the most important issues of energy politics is the expediency and economic efficiency in using energy carriers. It is for technological processes in various fields of industrial and agricultural production. Beside this, reducing the technogenic influence on the environment is an important issue. It will enable improvement of the environment.

Alternative energy is one of the directions of global energy development. The main advantage of this kind of energy that it is clean energy which can provide domestic and industrial areas independently and together with traditional energy.

1. OBJECTIVES - FORMULATION OF THE PROBLEM

According to the International Geological Congress, the main energy resources in the world are 5043 billion tonnes of coal, 2904 billion tonnes of brown coal, 240 billion tonnes of peat deposits, etc. Perhaps, previously unknown new deposits of coal, oil and gas will be discovered, which would hundredfold increase global fuel reserves, but there is no evidence for this [1].

Considering the limited scope of traditional fuel energy, it is necessary and important to ensure a high quality of life for future generations through a balanced solution of issues in the energy sector.

Wind and solar energy are among the most available renewable energies in the current conditions. However, in most solar installations differ in the complexity of their design or have low efficiency or require complicated electromechanical systems as well as guidance mechanisms.

2. ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Several works have been devoted the issue of installing solar systems, as well as their orientations relative to the horizon [2-6]. In theses works analyses of the potential and possibility using of solar energy in various territories of countries were conducted.

The ambit of the construction and technological solutions in solar heating systems is very wide [7]. However, an important step when installing solar heating system constructions is their orientation relative to the horizon. This problem has not been not analyzed in detail in the considered literature.

3. MAIN MATERIAL

The intensity of solar energy mainly depends on the height of the sun above the horizon. It is known that in the Ukraine the optimal collector angle to the horizontal for summer (seasonal) operation is $\varphi + 10°$ and for year-round operation it is $\varphi - 10°$, where φ - latitude [8, 9]. Furthermore, an important condition for efficient working of a solar collector (SC) is its orientation relative to the horizon [10]. That is why solar collectors on the territory of Ukraine should be oriented to the south.

The proposed solar heating system model has improved solar construction because the collector time performs the function of building roofing at the same. It allows a reduction in cost, increase in efficiency and simplification of the solar collector construction (Fig. 1). A combined solar heating system (SHS) in the gravity mode was investigated for various orientations relative to the horizon, namely for the north-west (N-W) and north-east (N-E), south-west (S-W) and south-east (S-E).

The main unchanging stages of research were:

1) the system, which was filled with fresh water before each test;
2) air was removed from the system;
3) the intensity of solar radiation was measured with a pyranometer;
4) the temperature of the heat carrier was measured by mercury thermometers at three points in the system (at the outlet of the combined SC, at the inlet of the combined SC and in the tank battery);

5) the outside air temperature and its speed were measured by a thermal electric anemometer TESTO 405 - V1.

It was shown that the change in the intensity of solar radiation energy I [W/m^2], during the day in the S-E orientation generates about 2 times more solar energy than the N-W orientation (Fig. 2).

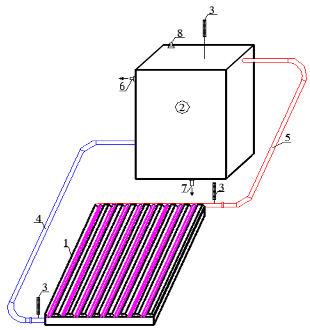

Fig. 1. Combined solar heating system (SHS) in gravity mode: 1 - solar collector; 2 - tank battery; 3 - thermometers; 4 - pressure pipeline; 5 - reverse pipeline; 6 - heat carrier pipe inlet; 7 - heat carrier pipe outlet; 8 - air release valve; 9 - tank of cold water

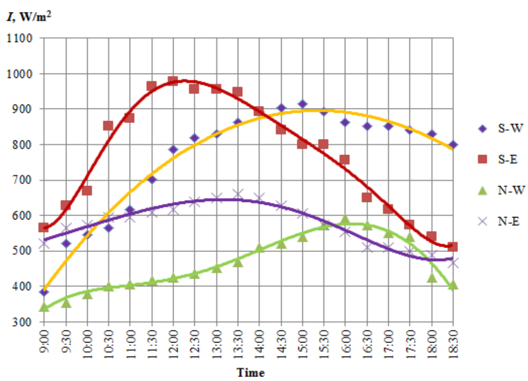

Fig. 2. Intensity of solar radiation energy on solar collector surface at different orientations relative to horizon

The specific thermal energy accumulated in the tank battery of the combined SHS Q_{SHS} [J per 1m^2] is determined by formula (1):

$$Q_{SHS} = \frac{m \cdot c \cdot (T_{outlet} - T_{inlet})}{F_{SC}} \quad (1)$$

where:

m - mass of the heat carrier in the tank battery [kg],

c - the average specific heat capacity (at constant pressure) at the arithmetic mean temperature of the heat carriers [J/(kg·K)],

T_{inlet}, T_{outlet} - heat carrier temperature at the SC inlet and outlet respectively [K],

F_{SC} - SC surface area [m^2].

The temperature change in the heat carrier shown in Figure 3, which was measured for each orientation.

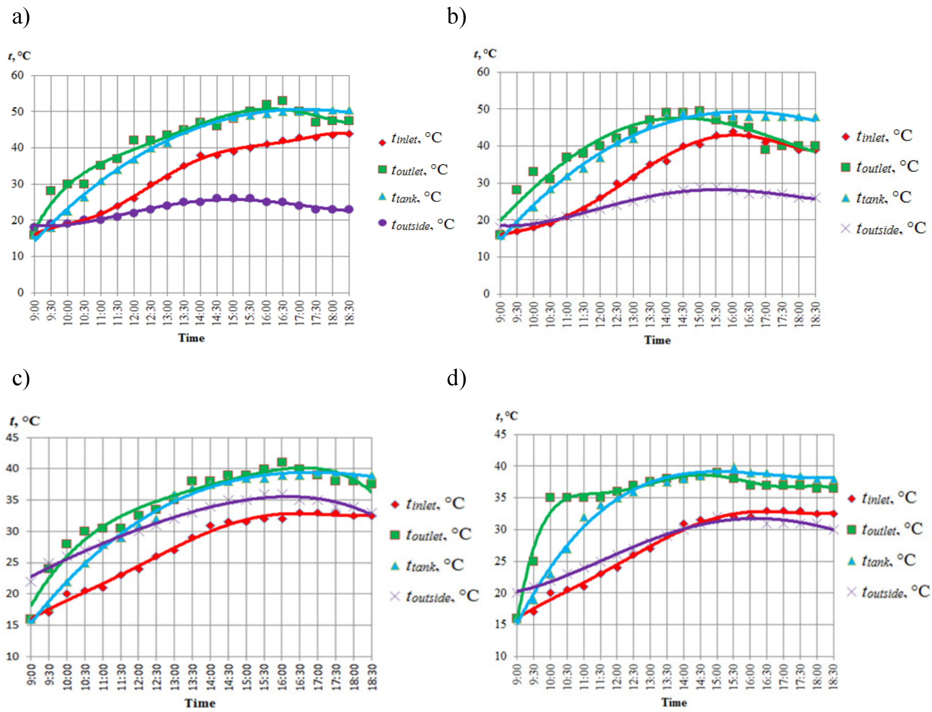

Fig. 3. Heat carrier temperature change during experiment at different orientations relative to horizon; t_{inlet} [°C] - inlet temperature of SC pipeline, t_{tank} [°C] - temperature in tank battery, t_{outlet}, [°C] - outlet temperature of SC pipeline, $t_{outside}$ [°C] - outside temperature (a) S-W, b) S-E, c) N-W, d) N-E)

From the results of experimental studies of the SHS graphs of the dependence of the efficiency and amount of specific thermal energy in a function of time in the gravity mode was obtained. These results are based on changes in the temperature of the heat carrier from the start of radiation.

The amount of specific thermal energy which accumulated in the tank battery at the different orientations gradually rose. For example, an interesting result is that the S-W orientation maximum was around 10000 kJ/m^2, while the N-W orientation was 33% less (Fig. 4).

The graph in Figure 5 shows the efficiency of using the experimental combined SHS in the summer time.

The efficiency of the SHS in accumulating heat energy in the tank battery, for example for the S-E orientation in the morning period exceeds 80 per cent. The dynamics of changes the efficiency of the system is linked to the momentary heat power of the SC. In the S-W orientation the momentary heat power of the SHS is 33% higher than in the N-W, moreover, the S-E direction differed from the N-E by 31%.

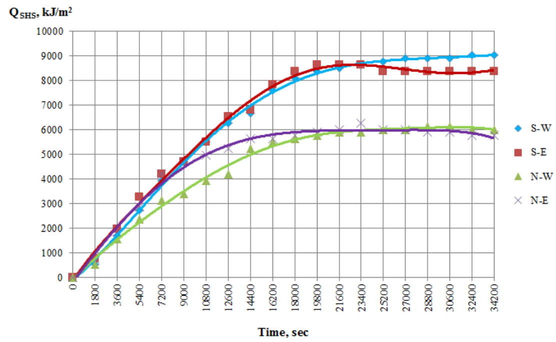

Fig. 4. Amount of specific thermal energy which accumulated in tank battery in combined SHS Q_{SHS}, kJ per 1 m^2 at different orientations relative to horizon

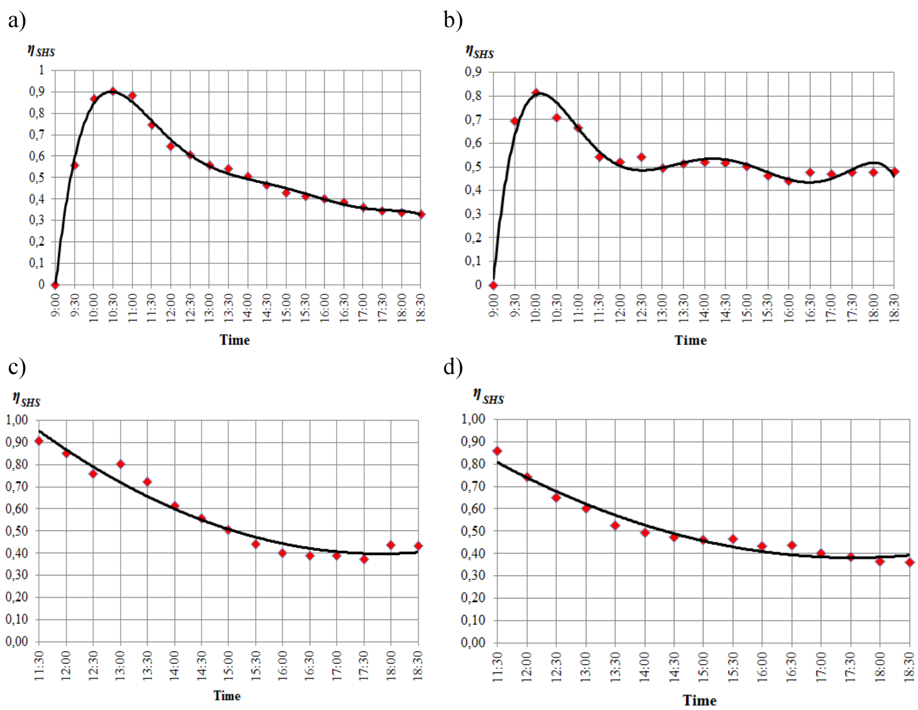

Fig. 5. Efficiency of SHS in gravity mode at different orientations relative to horizon (a) S-W, b) S-E, c) N-W, d) N-E)

CONCLUSIONS

By summarizing the above-mentioned data, it could be argued that the solar heating system model allows the temperature of the heat carrier in the solar system at different orientations relative to the horizon to be predicted during building design and construction. This gives the opportunity to choose the best conditions at the design stage to achieve the maximum temperatures of the combined solar heating system.

In the research experiments, the combined solar heating system at different orientations reached around 80% efficiency. This allows the authors to confirm the hypothetical idea of the possibility of widespread use of solar collectors combined with the building roof in solar heating systems.

In the gravity mode the heat carrier is heated from 16 to 50.5°C in the southwest direction. The maximum quantity of specific thermal energy which accumulated in the tank battery of the combined of solar heating system was 10 MJ/m^2.

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WPŁYW ORIENTACJI NA EFEKTYWNOŚĆ DZIAŁANIA KOLEKTORA SŁONECZNEGO PRACUJĄCEGO W TRYBIE GRAWITACYJNYM

Nowym kierunkiem w energetyce jest wykorzystanie odnawialnych źródeł energii. W artykule przedstawiono efektywność wytwarzania ciepła w układzie grzewczym z kolektorem słonecznym przy jego zróżnicowanym nachyleniu i orientacji względem stron świata. Zaprezentowano wykresy ilustrujące zmianę temperatury oraz ilość energii promieniowania słonecznego padającego na kolektor słoneczny podczas wykonywania eksperymentu. Ponadto, określono ilość i efektywność wytwarzania ciepła w badanym układzie kolektorowym.

Słowa kluczowe: **kolektor słoneczny, system grawitacyjny, kombinowany układ ogrzewania słonecznego, natężenie energii promieniowania słonecznego na powierzchni kolektora słonecznego, ciepło właściwe, efektywność energetyczna**