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Evaluation of the energy efficiency of the solar air collector with turbulators

Uzakov G.N., Ibragimov U.Kh.

DSc, Professor department of "Alternative Energy Sources"-Karshi Engineering Economics Institute, Karshi, Uzbekistan
PhD, Docent department of "Heat Power Engineering"-Karshi Engineering Economics Institute, Karshi, Uzbekistan

ABSTRACT: One of the methods of efficient use of solar energy is the use of solar air collectors, in which there are obstacles to the large-scale use of solar air collectors due to the low heat transfer process, the small thermal conductivity of air and the low rate of heat exchange between the air and the absorber. However, installation of turbulizers in order to accelerate thermal-hydrodynamic processes in solar air collectors gives good results. In this research work, the results of changing the energy UWC when installing flat (T model), perforated (TT model) and confusor (KT model) turbulizers in the air channel of solar air collectors are presented.Diurnal changes were experimentally studied. According to the results, the KT5 solar air collector has the highest energy UWC value, the energy UWC is 77%.

I. INTRODUCTION

Nowadays, solar air collectors (SAC) are widely used in the use of solar energy, which are simple in construction, convenient in operation, inexpensive, and do not have problems such as corrosion, boiling, leakage, and freezing. However, the low rate of heat transfer between the solar air collector absorber and the air and the small heat UWC significantly limit the fields of application of SAC. A large number of researchers have proposed SAC with various modifications to increase the heat transfer rate between the absorber plate and the air, and many theoretical and experimental studies have been conducted. Omojaro and Aldabbaghs [1] conducted an experimental study of the characteristics of the one-way and two-way solar air collector with steel wire mesh and longitudinal ribs attached to the absorber. According to the results, the efficiency of the solar air collector increased significantly when the grid absorber was used, and the thermal UWC and temperature difference were higher in the two-way solar air collector compared to the one-way solar air collector. UWC was maximum when the air mass consumption was 0.038 kg/s and made 63.74%. Mariana and others [2] When studying the thermal UWC of a two-way solar air collector, the temperature difference between inlet and outlet air reached 40℃ when the air velocity was 0.020 kg/s. Average daily efficiency was 42%, maximum efficiency was 50%. When the air mass consumption was 0.045 kg/s, the thermal UWC reached 60%, and the average temperature of the air at the outlet reached 46℃. Manjunath et al [3] combined the edged ribs to the absorber plate to improve the thermal characteristics of the solar air collector and conducted a numerical study using the CFD ANSYS Fluent 16.2 software tool. The effect of the geometric parameters of the edge ribs and the Reynolds number on the effective UWC was evaluated. The longitudinal pitch of the edge ribs is 30, 40 and 50 mm, and the diameter is 1, 1.6 and 2.2 mm. The presence of edge fins increased the heat exchange surface by approximately 53.8%, resulting in a 14.2% increase in the thermal UWC of the solar air collector. Edge fins are effective at low mass consumption of air, reaching a maximum effective UWC of 73%. Qamar et al. [4] conducted a numerical and experimental study of one-way SAC. The size of the solar air collector is 1220x610x65 mm, CFD modeling was used to predict the air consumption and temperature distribution to estimate the optimal performance parameters. When the mass consumption of air is 0.01 kg/s, the outlet temperature of the air is determined to be 82℃ according to the model, and 73℃ in the experiment. the pressure drop in the solar air collector is 4.34 Pa, the total heat loss coefficient is 2.27 W/(m^2 ℃), and the energy lost from the solar air collector is 37% of the total energy. Also, in the literature, there are a large number of research works dedicated to the energy analysis of SAC [5, 6], there is no information on the energy efficiency of SAC with holes and confusor turbulizers. It is known that the energy efficiency of the solar air collector is determined by the ratio of the amount of useful energy obtained by the air flow to the intensity of the incident solar radiation. The energy efficiency of the solar air collector is significantly dependent on several parameters, namely, the optical and thermal characteristics and shape of the absorber plate, the temperature of the external environment, wind speed, solar radiation intensity, the angle of incidence of sunlight, the angle of installation of the solar air collector, and the mass consumption of air. Based on the

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analysis of the above-mentioned literature, the aim of the study was to determine the change in the energy UWC value of the solar air collector with a smooth absorber and a turbulizer.

II. MATERIALS AND METHODS

The energy efficiency of any SAC is compared using heat and effective UWC. The thermal UWC value of SAC is determined as follows:

$$\eta_{SAC} = \frac{Q_u}{Q_t} \quad (1)$$

where Q_u is the useful energy obtained during the operation of SAC:

$$Q_u = mc_p(t_o - t_i) \quad (2)$$

where c_p is specific heat capacity of air, J/(kg·°C); t_i, t_o-temperatures of air inlet and outlet of the SAC, °C, m-mass consumption of air flowing through the SAC, kg/s:

$$m = \rho V A_{c.t} \quad (3)$$

where ρ is air density, kg/m^3; V-average speed of air, m/s; $A_{c.t}$-surface of the cross-sectional area of the air inlet hole, m^2.

The total amount of energy Q_t, falling on the SAC surface:

$$Q_t = SA_{QHK} \quad (4)$$

where S is solar radiation intensity, W/m^2; A_{SAC}- SAC absorption surface area, m^2.

So, the energy UWC value of SAC is as follows:

$$\eta_{en} = \frac{mc_p(t_o - t_i)}{SA_{SAC}} \quad (5)$$

Daily solar radiation and daily useful energy are calculated using the trapezoidal numerical integration method [7]:

$$Q_u = \int_{t_1}^{t_2} Q(t)dt = \frac{h}{2}[Q_{u1} + 2Q_{u2} + 2Q_{u3} + \cdots + Q_{un}] \quad (6)$$

$$I = \int_{t_1}^{t_2} I(t)dt = \frac{h}{2}[I_1 + 2I_2 + 2I_3 + \cdots + I_n] \quad (7)$$

where h-time gain, s; $Q(t)$-useful energy function obtained in the time interval; $I(t)$-function of solar radiation intensity over time; t_1, t_2-start and end time.

III. RESULTS AND DISCUSSION

The energetic and effective UWC of SACs with smooth absorbers and turbulizers were calculated based on the values of air inlet and outlet temperatures, mass consumption of air, solar radiation intensity and total lost pressures in SACs determined as a result of theoretical and experimental studies of SACs with smooth absorbers and turbulizers. In the calculations, the speed of the air flow was 4 m/s and the temperature of the inlet air was taken equal to the temperature of the outside air.

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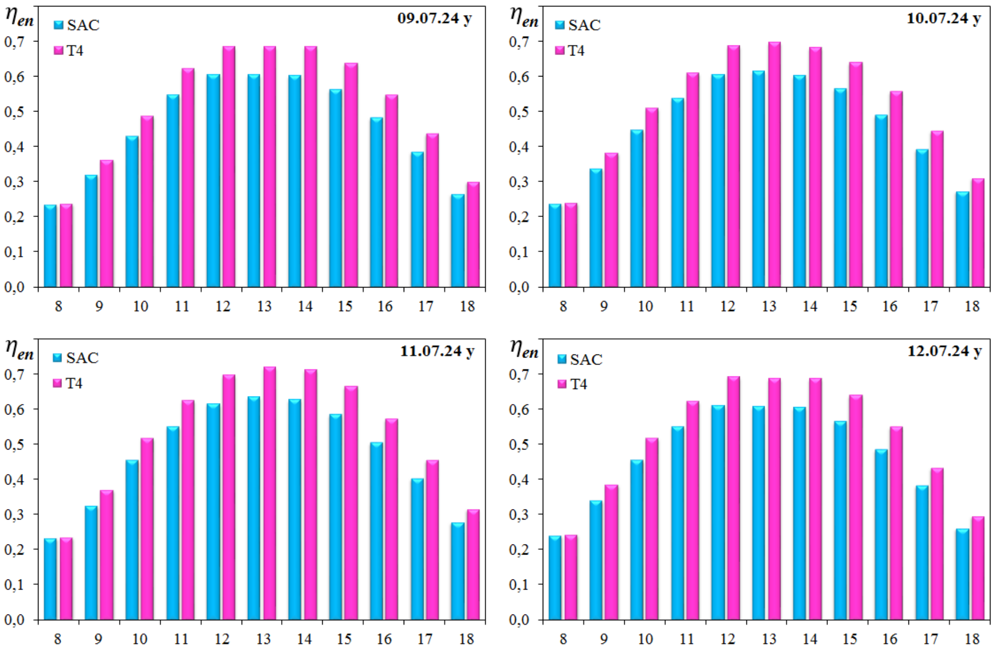

Fig.1. The results of changing the value of energy UWC in the T4 model.

The experimentally determined value was obtained for the solar radiation intensity. In the results obtained in all models for energy UWC, the value of energy UWC increased to the maximum value from 8^{00} to 14^{00} hours, and decreased from 14^{00} to 18^{00} hours. The results of the energy UWC values obtained in the T4 model are shown in Fig. 1. As can be seen from the results presented in Fig.1 above, the energy UWC value of the T4 model is higher than the energy UWC value of the smooth absorber SAC. The maximum value of energetic UWC in SAC with smooth absorber is as follows: 0.60 on July 9, 0.61 on July 10, 0.63 on July 11, 0.61 on July 12. The maximum value of the energetic UWC in the T4 model is as follows: 0.68 on July 9, 0.70 on July 10, 0.72 on July 11, and 0.69 on July 12. In the T4 model, the energy UWC value was on average 1.13 times higher than that of the SAC with a smooth absorber. The results of the energy UWC values obtained in the T5 model are shown in Fig.2. As can be seen from the results presented in Fig.2, the energy UWC value of the T5 model is higher than the energy UWC value of the smooth absorber SAC. The maximum value of energetic UWC in the T5 model is as follows: 0.70 on July 9, 0.71 on July 10, 0.73 on July 11, 0.70 on July 12. In the T5 model, the energy UWC value was on average 1.16 times higher than the SAC with a smooth absorber.

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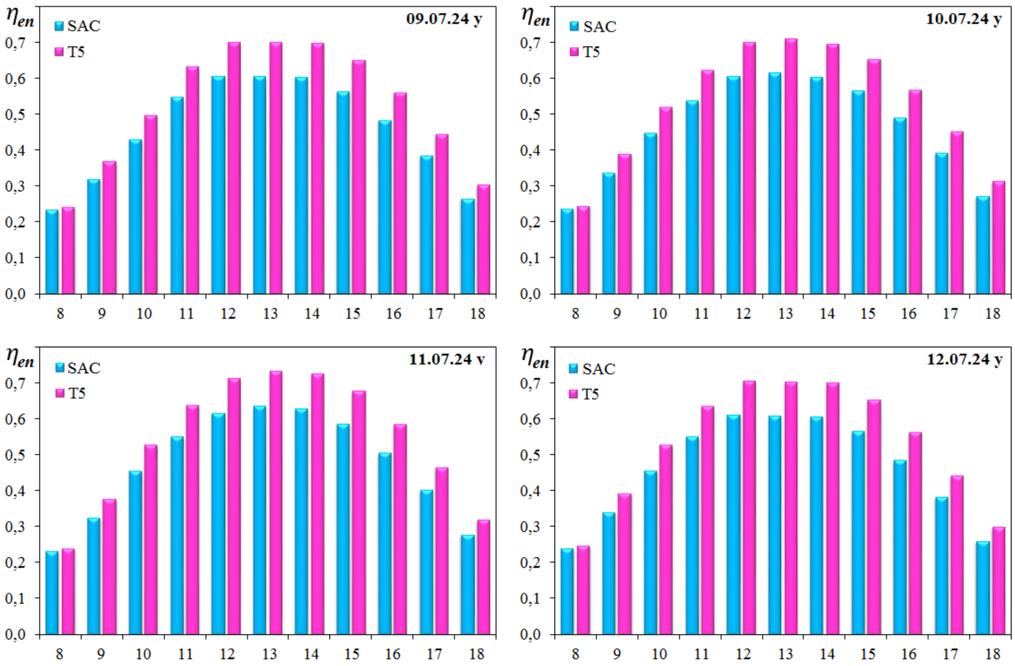

Fig.2. The results of changing the value of energy UWC in the T5 model.

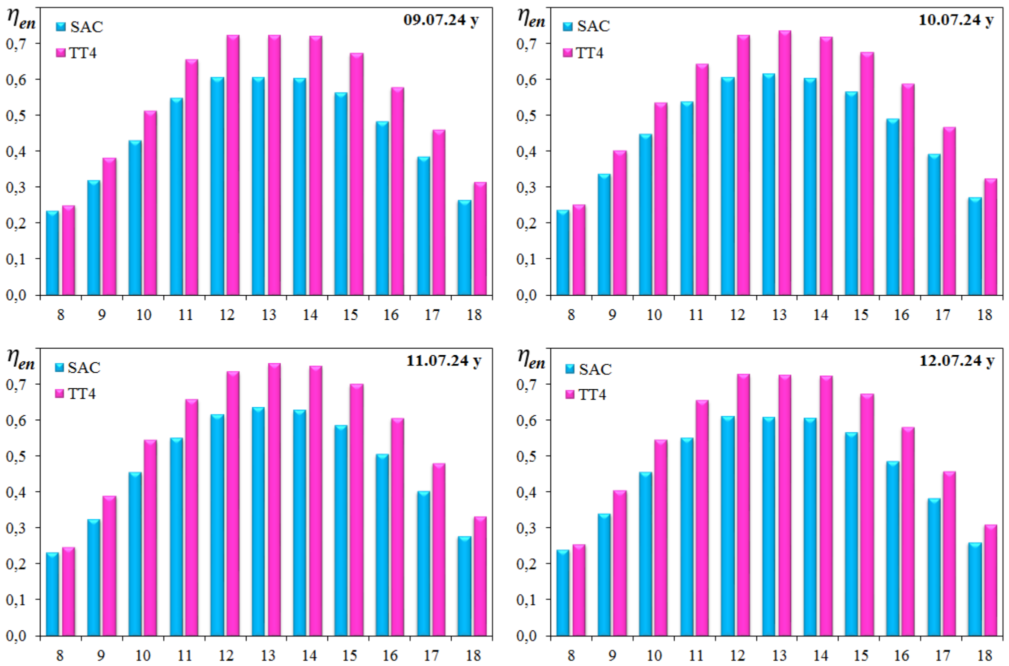

Fig.3. The results of changing the value of energy UWC in the TT4 model.

The results of the energy UWC values obtained in the TT4 model are shown in Fig.3. From the results presented in Fig.3, it can be seen that the energy UWC value of the TT4 model is higher than the energy UWC value of the smooth absorber KHK. The maximum value of energetic UWC in the TT4 model is as follows: 0.72 on July 9, 0.73 on July 10, 0.76 on July 11, 0.73 on July 12. In the TT4 model, the energy UWC value was on average 1.19 times higher than in the smooth absorber SAC.

The results of the energy UWC values obtained in the TT5 model are shown in Fig. 4. As can be seen from the results presented in Fig.4, the energy UWC value of the TT5 model is higher than the energy UWC value of the smooth absorber SAC. The maximum value of energetic UWC in the TT5 model is as follows: 0.74 on July 9, 0.75 on July 10, 0.77 on July 11, 0.74 on July 12. In the TT5 model, the energy UWC value was on average 1.22 times higher than the SAC with a smooth absorber.

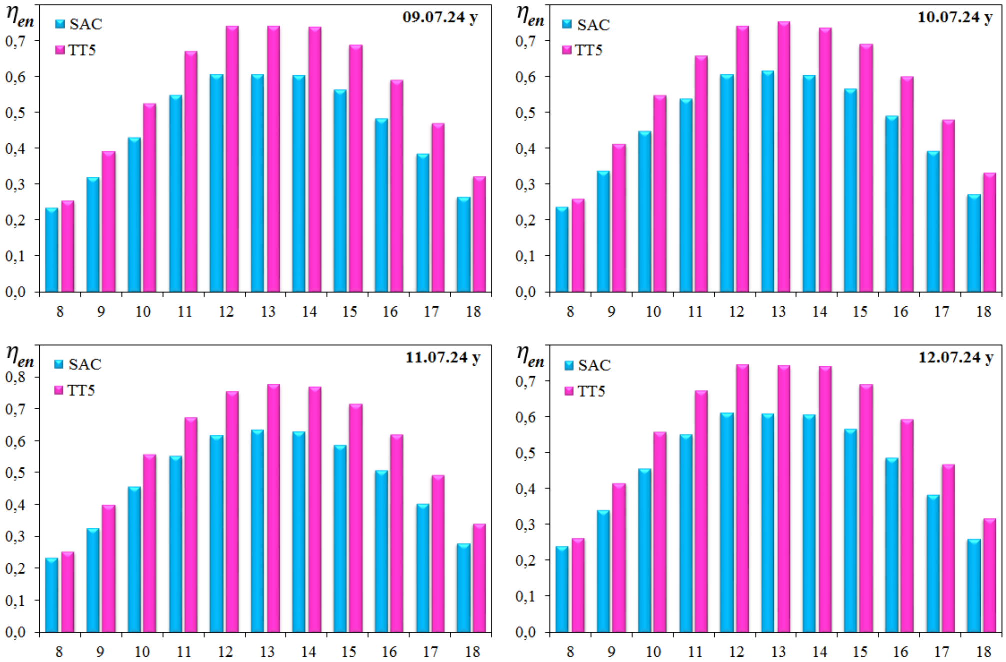

Fig.4. The results of changing the value of energy UWC in the TT5 model.

The results of the energy UWC values obtained in the KT4 model are shown in Fig. 5. As can be seen from the results presented in Fig.5, the energy UWC value of the KT4 model is higher than the energy UWC value of the SAC with a smooth absorber. The maximum value of energetic UWC in KT4 model is as follows: 0.78 on July 9, 0.79 on July 10, 0.81 on July 11, 0.78 on July 12. In the KT4 model, the energy UWC value was on average 1.29 times higher than the SAC with a smooth absorber.

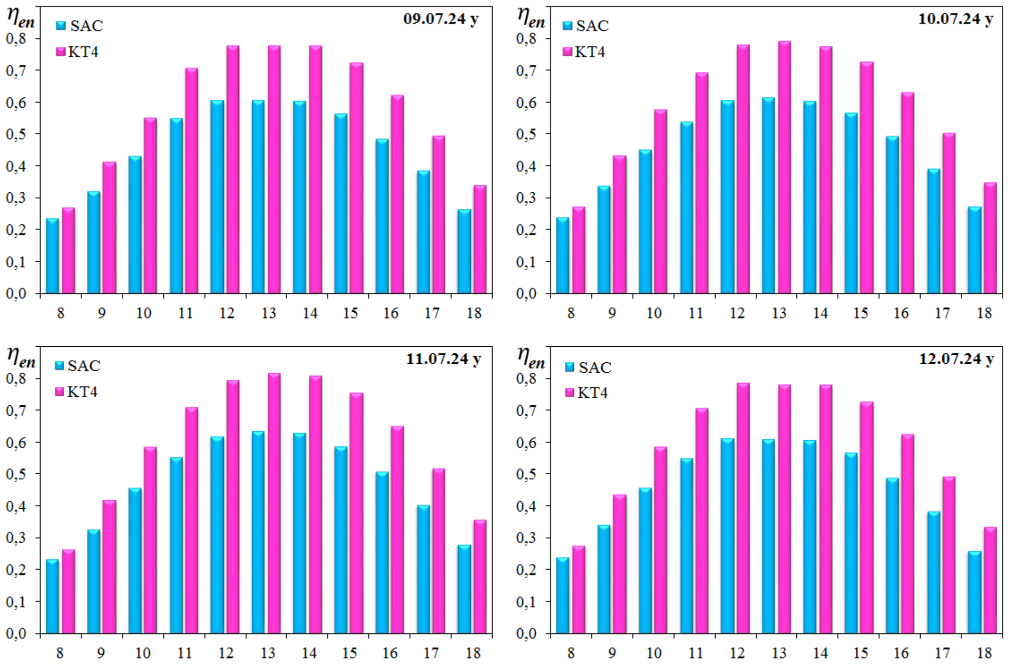

Fig.5. The results of changing the value of energy UWC in the KT4 model.

The results of the energy UWC values obtained in the KT5 model are shown in Fig.6. As can be seen from the results presented in Fig.6, the energy UWC value of the KT5 model is higher than the energy UWC value of the smooth absorber SAC. The maximum value of energetic UWC in the KT5 model is as follows: 0.74 on July 9, 0.75 on July 10, 0.77 on July 11, 0.74 on July 12. In the KT5 model, the energy UWC value was on average 1.32 times higher than that of the SAC with a smooth absorber.

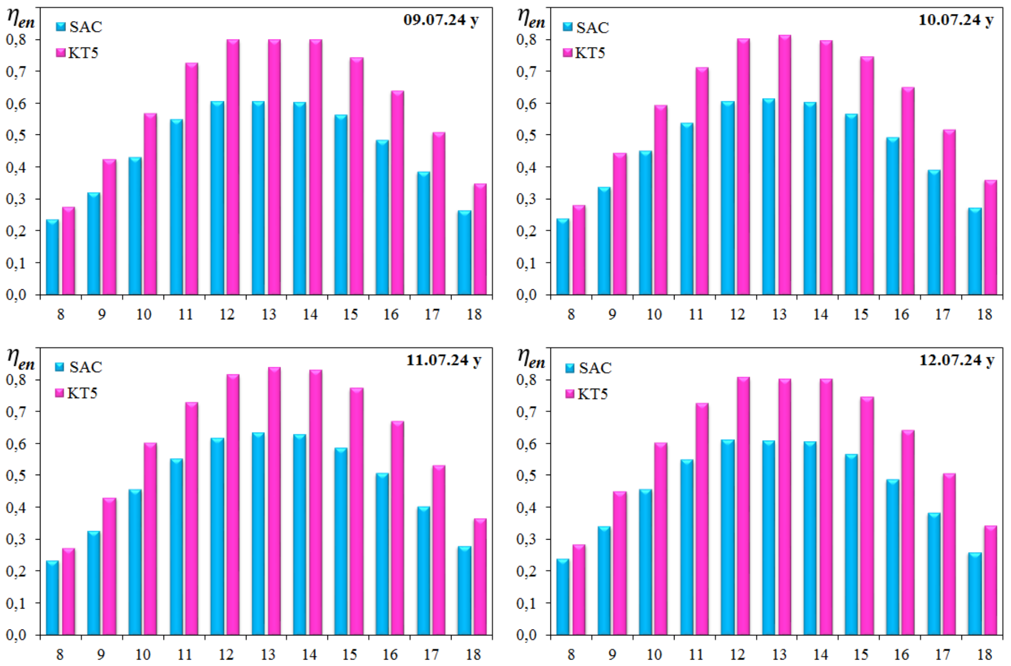

Fig.6. The results of changing the value of energy UWC in the KT5 model.

The hourly results of changes in energetic UWC in all models of SAC were summarized and the results of comparison by days are presented in Fig.7.

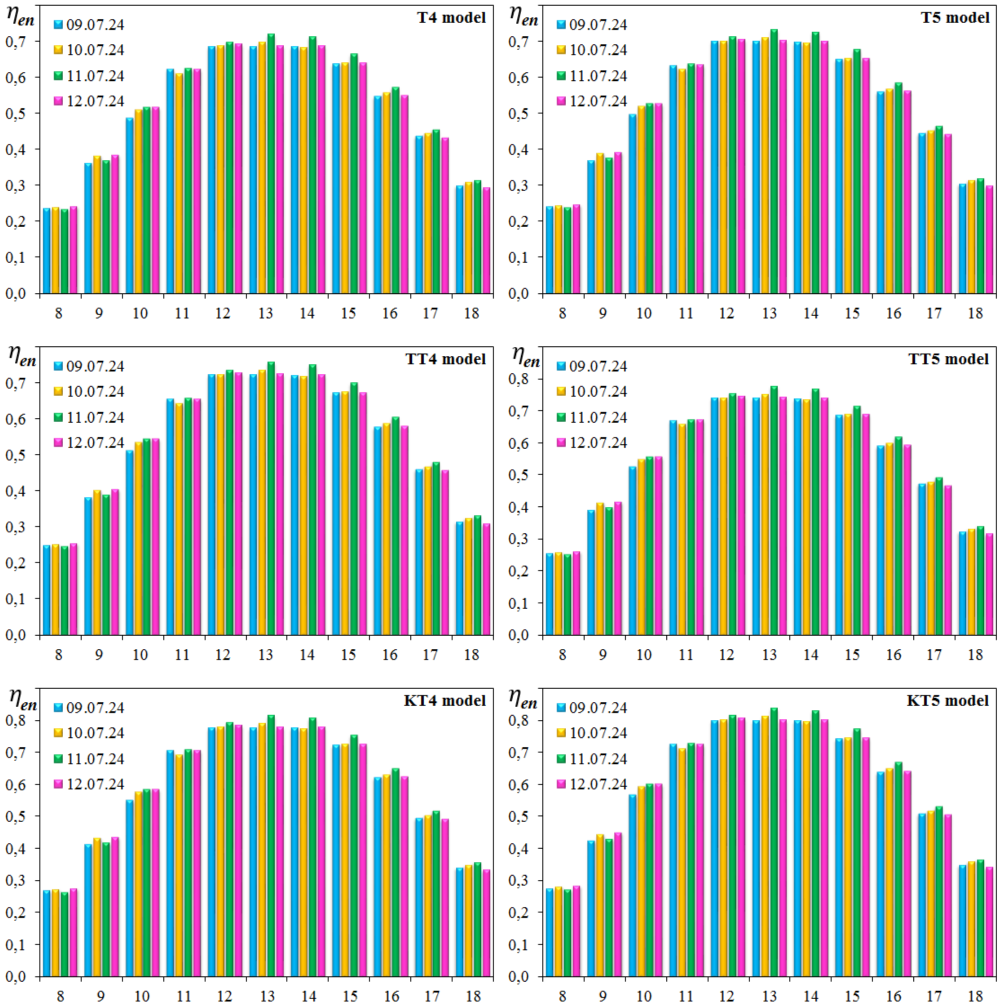

Fig.7. Results of daily change of energy UWC value.

In this case, the average values of the energetic UWC obtained during four days were compared and it was determined that the energetic UWC increased. As it can be seen from the analysis of the results obtained on the change of energetic UWC values, the change of energetic UWC depends on the amount of useful energy obtained, the intensity of solar radiation and the heat exchange surface of the SAC absorber. The value of UWC was found to be the highest. The main reason for this is the large heat exchange surface in the KT5 model compared to other models. When all models are compared, the value of energy UWC in the KT5 model is 15.7% compared to the T4 model, 14.1% compared to the T5 model, 11.0% compared to the TT4 model, 8.0% compared to the TT5 model, and 8.0% compared to the KT4 model It was found to be 2.5% higher.

IV. CONCLUSION

The energetic UWC value of SAC with smooth absorber and turbulizer was determined on the basis of experimental studies conducted from July 9 to July 12, 2024, in which the energetic UWC value obtained in all models on July 11 is the highest, which is justified by the high intensity of solar radiation.

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The energy UWC values determined on July 11, 2024 are 0.63 for the smooth absorber SAC, 0.72 for the T4 model, 0.73 for the T5 model, 0.76 for the TT4 model, 0.77 for the TT5 model, 0.81 for the KT4 model, and 0.84 for the KT5 model. times was found to be higher.

Compared to other models, the energy FIK value of smooth absorber and turbulizer is the highest in the KT5 model, 15.7% compared to the T4 model, 14.1% compared to the T5 model, 11.0% compared to the TT4 model, 8.0% compared to the TT5 model and 2.5% compared to the KT4 model.

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