ISSN 2181-8622

Manufacturing technology problems

Scientific and Technical Journal Namangan Institute of Engineering and Technology

Volume 9
Issue 2
2024

INVESTIGATION OF AN IMPROVED SOLAR WATER HEATER IN COMSOL MULTIPHYSICS SOFTWARE

ALIEV RAYIMJON

Professor of Andijan State University, Andijan, Uzbekistan
E-mail.: alievuz@yahoo.com

ERALIYEV ABDUKHALIL

PhD student of Andijan State University, Andijan, Uzbekistan
Phone.: (0894) 701-2933, E-mail.: eraliyevabduxalil70@gmail.com

NOSIROV MURODJON

Professor of Andijan State University, Andijan, Uzbekistan
Phone.: (0890) 549-8149, E-mail.: nmz1964@yahoo.com

MIRZAALIMOV AVAZBEK

Senior Teacher of Andijan State Pedagogical Institute, Andijan, Uzbekistan
Phone.: (0897) 273-4808, E-mail.: avazbek.mirzaalimov@mail.ru

MIRZAALIMOV NAVRUZBEK

Senior Teacher of Andijan State University, Andijan, Uzbekistan
Phone.: (0897) 755-9300, E-mail.: mirzaalimov90@mail.ru
*Corresponding author

Abstract: In the article, considering that the use of renewable energy sources is the most promising in the conditions of the current energy needs, increasing their efficiency is one of the urgent problems. Speed distribution, temperature distribution, water density change due to thermal expansion were analyzed. The temperature of the solar collector, which is one of the most important parameters, is that the maximum temperature of the ordinary solar collector produced in the industry is 60.4 oC and the maximum temperature of the improved solar collector is 65.2 oC, and the temperature difference is equal to 4.8 oC determined. Comparing the results obtained through modeling, it is found that the proposed improved solar collector is 8% more efficient in obtaining hot water in the same time interval due to its new optimal design. The proposed device allows to obtain hot water due to the use of solar energy. By widely introducing the improved solar collector, it will be possible to meet the needs of the population for hot water, to use the electricity saved due to the reduction of water heating by electricity for other purposes.

Keywords: solar water collector, Comsol multiphysics, optimal design, temperature distribution, high efficiency.

Introduction. In order to prevent the catastrophe of the globe due to global warming, it is necessary to reduce the emission of greenhouse gases into the atmosphere. One potential solution to this problem is the widespread use of renewable energy sources. Solar energy will play an important role in meeting future energy demand. 3,400,000 Exa-Joules of solar energy fall on the earth from the sun in a year. It can meet current world energy consumption with just 1 hour and 15 minutes of radiation [1]. However, very little of human energy consumption is currently met by solar energy. According to REN21, the use of solar energy will increase significantly from 2030. For this reason, research on efficient use of solar energy has increased significantly [2]. The industry related to the use of solar energy is constantly developing all over the world. This is due to the doubling of the energy demand and the limitation of the primary energy source due to the depletion of fossil fuels [3]. Solar energy can be collected by solar photovoltaic and solar thermal methods. In solar thermal method, solar energy is used as thermal energy for several energy devices such as solar drying process [4], solar adsorption cooling [5], solar desalination [6,7,8], solar water heater [9], solar cooker [10] can be used.

According to statistics, one person in Uzbekistan needs an average of 15-20 liters of hot water every day. Currently, hot water requirements are mainly met by using electric heaters and natural gas. In fact, this type of energy is in great demand for other purposes during the day. As a result, the price of hot water increases. Rising energy prices, environmental concerns, and dwindling reserves of primary energy sources require less use of electric heaters. In addition, with the increase in the population, the demand for electricity is growing rapidly. During periods of peak demand for hot water, power generation facilities are overloaded, resulting in power outages. It is desirable to solve these problems by obtaining hot water without using electricity. For this, solar hot water supply systems can be widely used for domestic and commercial purposes. These systems use solar energy to generate hot water. It is possible to get hot water at low prices with the help of current technologies.

Research methods. With the help of vacuum tube collectors, it is possible to obtain hot water with a temperature of up to 100°C at normal atmospheric pressure. Such a solar hot water system usually transfers heat by natural circulation due to the buoyancy of the temperature difference between the two regimes (Figure 1). Therefore, they do not require the use of pumps. They are the most commonly used solar water heaters for domestic use.

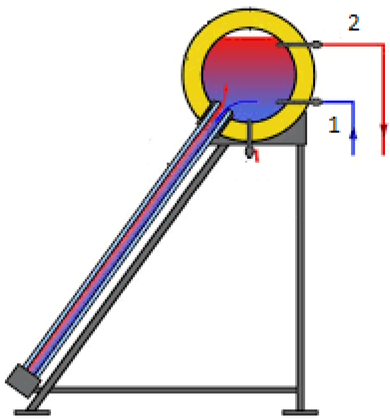

Figure 1. Side view of an industrial solar water heating collector. 1- cold water inlet pipe, 2- hot water pipe leaving the collector.

The collector is installed at an angle of 35-50° relative to the horizon, depending on the location of our country, so that the amount of rays coming from the sun constantly falls on the collector. A heat absorbing material was placed inside the vacuum tube to ensure more absorption of the rays.

Currently available solar collectors do not use a part (30-40%) of the light energy falling on the entire surface of the collector. This work deals with the adoption of an innovative experimental technology of increasing the efficiency of a modern solar water heater by installing a reflective base between the base and the pipes . A typical solar water heater uses only the light that falls on the tubes on the top of the unit. In the device we propose, the beam passing through the tubes falls on the underside of the tubes as a result of hitting the base and returning. This helps to increase its efficiency (Fig. 2).

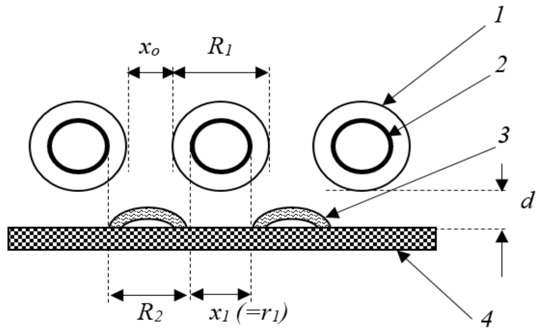

Figure 2 . An improved solar water heater
1. Device tube outer shell, 2. Device tube inner shell, 3. Reflector base.

We know that nowadays science cannot be imagined without computer programs. The program is the cheapest and most imaginative tool for obtaining technical results. However, it will be necessary to make sure that the result obtained in the program is correct. Solar collectors were studied in "Comsol multiphysics" program. The result was compared with the theories in the literature and a general conclusion was made. The pressure is 101330 Pa, the solar intensity on the surface of the collector is 1000 W/m ^{2}, the inner radius of the pipe is 2 cm, and the length is 165 cm, the speed of the water in the pipe is 0.0001 m/s, the temperature of the water at the entrance to the pipe is 293.15°K, the calculation time is 17 min 48 Results were obtained for the case with s and the following results were obtained.

Results and discussion

1. Fluid movement in pipes is based on the literature that the flow velocity of the liquid in the pipe near the surface is small and increases as it approaches the center. The results of the flow velocity in the pipe obtained in the Comsol multiphysics program are shown in Fig. 2.

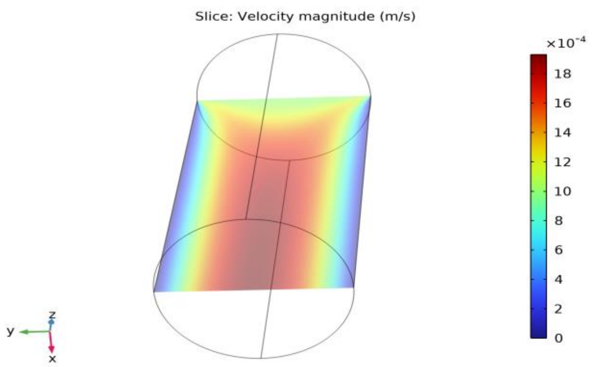

Figure 2. Velocity distribution in the collector pipe.

It can be seen from the figure that the maximum speed in the center is $19 \cdot 10^{-4}$ m/s, and the speed at the edge is close to 0. So we can see that the results in the program are correct.

2. It is known that with increasing temperature, the volume of water increases, and the density of water of constant mass decreases. In the Comsol multiphysics program, this process is graphically depicted in Figure 3.

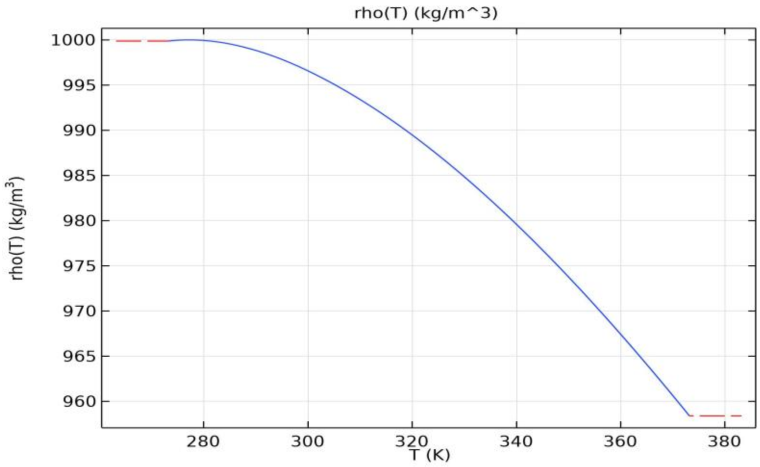

Figure 3. Dependence of density change on temperature.

Figure 3 shows that the density of water decreases to 955 kg/m ^{3} at the boiling point.

Now let's see how the most important parameter of the collector - water temperature changes. After the light falls on the collector, its temperature rises. As the temperature rises, a difference in density is formed in the liquid, and a flow occurs. The temperature also varies at different points. Because hot water has a low density, the temperature is high at the top, and cold water, which is denser at the bottom, has a low temperature. This situation can also be seen in the result obtained in Comsol (Figure 4).

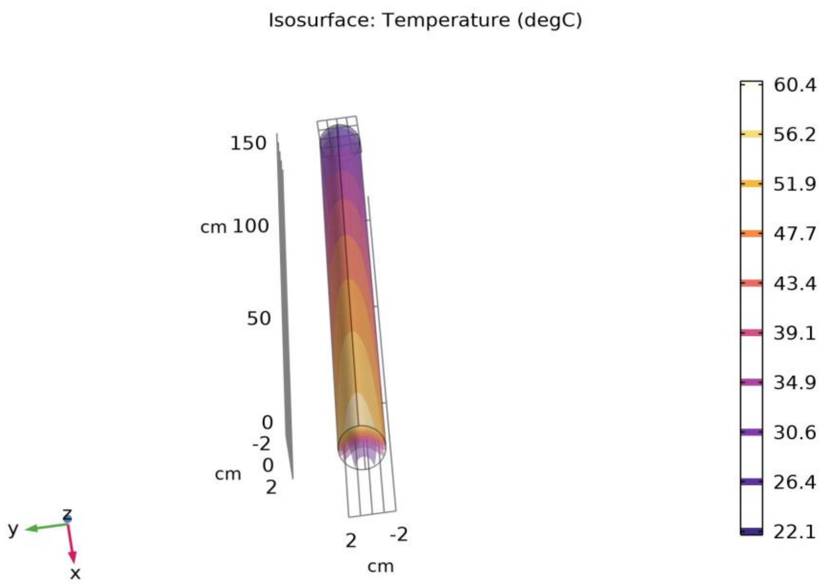

Figure 4. Water temperature distribution in the collector pipe.

The results show that the temperature of the liquid increases from 293 K to 333.4 K due to the energy received from the sun.

In obtaining the velocity distribution, the program determines by solving the following equations imposed on it, and it is correctly identified for all cases.

$$\rho(\mathbf{u}\cdot\nabla)\mathbf{u} = \nabla\cdot[-p\mathbf{I} + \mathbf{K}] + \mathbf{F}$$

$$\rho\nabla\cdot\mathbf{u} = 0$$

The temperature equation corresponds to the differential form of Fourier's law, which can include additional cases such as heat sources. The heat balance equation for the collector is as follows.

$$\rho C_p\mathbf{u}\cdot\nabla T + \nabla\cdot\mathbf{q} = Q + Q_p + Q_{vd}$$

$$\mathbf{q} = -k\nabla T$$

Figure 6 shows the result of modeling the temperature distribution in the proposed improved solar water heating collector under the same conditions and times as in Figure 4 above in the normal collector in Comsol Multiphysics.

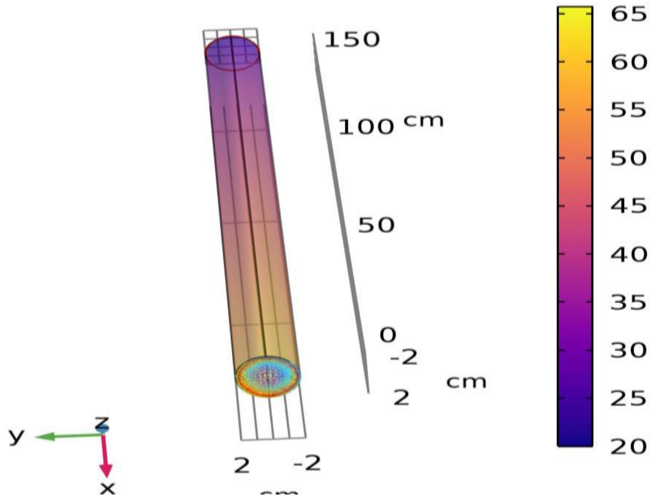

Figure 6. Temperature distribution in an improved solar collector in Comsol Multiphysics

From the results obtained by modeling, it can be seen that the improved solar water heating collector has a uniform velocity distribution in the movement of liquids in the pipes, as well as a decrease in its density due to the expansion of the liquid due to heat, compared to the collectors produced in the ordinary industry. The temperature, which is considered one of the most important parameters of solar collectors, in the Comsol Multiphysics program, under the same conditions and at the same time, the maximum temperatures of simple (60.4 °C) and improved (65.2 °C) solar water heating collectors shown in Figure 4 are 4.8 °C was found to differ from The modeling results obtained during the research revealed that the proposed improved solar water heating collector is 8% more efficient in obtaining hot water in an 18-minute experiment due to its newly developed optimal design compared to the solar water collectors produced in the industry. In the future research work, it is aimed to extend the experimental time through modeling and to carry out experimental research work for both devices in natural conditions.

Conclusion. Based on the above results, the improved solar water heating collector created in the Comsol Multiphysics program was studied and it was found that the new design developed is more efficient than the prototypes currently being produced in the industry. By comparing the thermal parameters of the results obtained in the program with the experimental results determined in international scientific publications, it was determined that the results obtained by modeling corresponded (collibrovka). The speed distribution in the movement of liquids in pipes obtained in the program, as a result of the expansion of the liquid due to heat, its density decrease is exactly consistent with the previously known results. The temperature, which is one of the most important parameters of the solar collector , was found to differ by 4.8 °C in the maximum temperatures of simple (60.4 °C) and improved (65.2 °C) solar collectors under the same conditions and at the same time in the Comsol Multiphysics program. The modeling results obtained during the research revealed that the proposed improved solar water heating collector is 8% more efficient in obtaining hot water in the same period of time due to its new optimal design compared to the solar water collectors produced in the industry.

Allows to obtain hot water by using solar energy while using renewable energy sources. By widely introducing the improved solar water heater collector, it will be possible to meet the needs of the population for hot water, and to use the electricity saved for other purposes by reducing the water heating by electricity.

References

[1] Thirugnanasambandam M., Iniyan S. and Goic R. 2010 Renewable and Sustainable Energy Reviews 14 312-322.

[2] Kannan N. and Vakeesan D. 2016 Renewable and Sustainable Energy Reviews 62 1092-1105.

[3] Ambarita H. 2017 Journal of Physics: Conference Series 801(1), 012093.

[4] Dina S. F., Ambarita H., Napitupulu F. H. and Kawai H. 2015 Case Studies in Thermal Engineering 5 32-40.

[5] Ambarita H. and Kawai H. 2016 Case Studies in Thermal Engineering.

[6] Ambarita H. 2016 Case Studies in Thermal Engineering 8 346-358.

[7] Ambarita H. 2016 IOP Conference Series: Materials Science and Engineering 180(1) 012024.

[8] Setyawan EY, Napitupulu RAM, Siagian P. and Ambarita H. 2017 IOP Conference Series: Materials Science and Engineering 237 012012.

[9] Ambarita H. and Sitepu T. 2017 IOP Conference Series: Materials Science and Engineering 237 012014.

[10] Sitepu T., Gunawan S., Nasution DM, Ambarita H., Siregar RET and Ronowikarto AD 2016 IOP Conference Series: Materials Science and Engineering 180(1) 012032.

CONTENTS