V International Scientific and Technical Conference Actual Issues of Power Supply Systems

Technical Solutions for a Small-Scale Solar Oven

AIPCP25-CF-ICAIPSS2025-00309 | Article

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Iqboljon Anarboyev [a], Abduvohid Mamirov, Islombek Xojimatov

Andijan State Technical Institute, Andijan, Uzbekistan

[a)] *Corresponding author:* iqboljon.anarboyev@mail.ru

Abstract. Today, solar ovens that produce high temperatures are widely used in various fields due to their simplicity and low cost.However, the fact that not all solar ovens can produce high temperatures has significantly limited the scope of application of solar devices. It is possible to use solar energy to boil water, produce steam, cook some foods, melt solids that liquefy at high temperatures, weld, and generate electricity by collecting or concentrating solar radiation. The rapid development of industrial enterprises and production sectors in the world is causing energy dependence even in developed countries.One of the main tasks of measures aimed at solving the energy problem is the effective and rational use of alternative energy sources. In particular, in recent years, solar cells, solar heaters, solar convectors, and solar ovens based on the semiconductor photovoltaic effect have been widely used.

INTRODUCTION

The rapid growth of industrial enterprises and production sectors in the world is causing energy dependence even in developed countries. One of the main tasks of measures aimed at solving the energy problem is the effective and rational use of alternative energy sources. In particular, in recent years, solar panels, solar heaters, solar convectors, and solar ovens based on the semiconductor photovoltaic effect of solar energy have been widely used [1].

In particular, there are many methods for the effective use of solar energy in the world, and solar furnaces and solar concentrators are used in many areas for the effective use of solar energy. In addition, measures are being taken to effectively use solar energy to solve one of the main problems in the development of the field of materials science, the energy problem. Alternative and renewable energy sources are gaining importance with their widespread use in semiconductor materials science and materials science [2]. As a result of reforms and scientific research carried out in leading scientific research institutes in the world, intensive work is being carried out to meet the energy needs of materials science and semiconductor materials science, and work is being carried out to increase the efficiency of the widespread use of alternative energy sources in the field of materials science [3].

Solar concentrators have been created to use solar energy as thermal energy, and large solar concentrators are currently operating in France and Uzbekistan. One of the largest solar concentrators in the world was built near the village of Odeyo in France at an altitude of 1676 m above sea level based on the project of Felix Trombe. The power of these two solar furnaces is the same, the reflecting surface of the parabolic mirror mounted on the wall of a building 50 m high is 3000 m^2, the cross-sectional area is 2000 m^2. 63 flat mirrors - heliostats, each with a surface of 45 m^2, are placed on an inclined plane, which direct sunlight onto the parabolic mirror[3]. The focal length of the mirror is 18 m, the temperature at the focus reaches 3000^o C. The power of the concentrators is 1000 kW. Figure 1 shows a general view of solar concentrators in Uzbekistan and France[4]. If a 12 mm thick steel plate is placed at the focus of this concentrator, a hole large enough for a soccer ball to pass through will form in less than a minute.

a) b)

Figure 1. Here is a) a solar concentrator located in Uzbekistan, b) a solar concentrator located in France.

PROBLEM FORMULATION

The high temperature at the focus allows melting materials with temperatures up to T ~ 3000° C. However, the operation of such giant solar furnaces and their transportation from one place to another poses a number of problems [5]. This can be a partial obstacle to ongoing scientific research. High temperatures are very important in obtaining new types of materials, affecting the purity of the obtained materials, and if the solar furnace device is small in size and allows it to be used in any area, it increases the possibility of reducing various costs. It is known that the flow of solar radiation can be concentrated using lenses and reflectors, and currently lenses with convex sides are used that have the property of concentrating a bunch of parallel rays falling on them at one point - the focus. Lenses can be made in different sizes and used for different purposes.

The lenses must be made of very clean glass and the curved surface must be very well polished, otherwise various defects will increase in the prepared glass mirrors [6]. Therefore, although the manufacture of concentrators from lenses is not currently widespread, reflector-type concentrators are used to collect solar radiation. Mirror mirrors and polished aluminum mirrors are used to reflect and focus light. The reflection coefficient of mirror mirrors is approximately 0.8, the reflection coefficient of polished aluminum is around 0.75. In recent years, polyethylene terephthalate film coated with aluminum, with a reflection coefficient of up to 0.9, has also been increasingly used in the manufacture of concentrators. Depending on the required concentration, the reflecting surfaces can be 1) paraboloid, 2) parabolotylindrical, 3) facet, 4) conical. Now let's get acquainted with the concept of the degree of concentration of return concentrators. The surface formed by the rotation of a parabolic curve about its axis of symmetry is a paraboloid surface.

SOLUTION OF THE PROBLEM

In recent years, the methods for creating and effectively using small-sized solar concentrators have been developed, but the expected results are low, they are not adaptable to any conditions, and their optical properties are somewhat difficult to analyze. There is increasing interest in analyzing the physical and technical solutions of solar concentrators and improving their efficiency.

To date, the methods for creating and effectively using small-sized solar furnaces have been developed, but the expected results are low, they are not adaptable to any conditions, and their optical properties are somewhat difficult to analyze. This reduces the possibilities of using the device effectively [7].

In recent years, researchers have proposed solar furnaces with various designs. However, they are also not without their own shortcomings.

RESULTS AND DISCUSSION

Solar furnaces, as devices that generate high temperatures, are considered to be less expensive than other types of devices and are environmentally friendly energy, which is also of great importance in preventing today's energy shortage. The design and construction of large-sized solid-mirror solar furnaces have various technical and economic disadvantages, which limit their use in any conditions. For example, special molds and devices are required to build a solid-mirror solar furnace with a diameter of more than d ~3 m. The integrity of the prepared mirror is important. Even a small mechanical crack or fracture can lead to the unusability of the entire mirror. This, in turn, requires the complete replacement of the mirror. Therefore, instead of a solid mirror, it is advisable to build a large solar furnace consisting of separate mirror fragments [8]. Because it allows for the cleaning and replacement of small-sized facets in case of breakage. There are two main types of solar furnaces, one of which is controlled by a special automatic device to keep the temperature at the focus constant throughout the day. Large-diameter concentrators are difficult to operate. However, it is very difficult to maintain the focal plane in exactly the same position in such furnaces with a moving concentrator. The possibility of operating large-diameter concentrators is very low, and in the second type of furnaces, the concentrator is fixed and the sunlight is directed to the concentrator using flat mirrors that move behind the sun, called heliostats [9]. The reflecting surface of the flat mirrors of the heliostat must not be smaller than the reflecting surface of the concentrator. Otherwise, the concentrator surface will not be filled with light, which will lead to a decrease in the useful work coefficient.

Taking into account the above shortcomings, the solar furnace we propose differs from other types of furnaces in its low cost, its construction made of secondary materials, and its flexible design in any conditions, and most importantly, its high temperature at the focus[10]. To do this, the mechanism for concentrating sunlight in it is based on coatings with high optical properties (facets). Below, we will consider the problems of coating coatings with high optical properties (facets) and their technical solutions in the development of the design of the “solar furnace” device.

To do this, first of all, it is necessary to perform the following tasks:

-study the types of coatings and their application, classification, types of coating materials according to the nature;

-to select coatings with high optical properties (facets) to create the design of the solar furnace device and solve the coating methods for the structure;

-to analyze the problems of using solar energy, methods of using the solar furnace in different conditions and types of devices;

-The study of the importance of adhesives and methods of their use in coating metal surfaces with high optical properties (facets) in the preparation of solar furnace devices, as well as the development of a technology for coating coatings with high optical properties (facets) using adhesives, is one of the main problems.

Coating technology is widely used compared to other technologies due to its simplicity and accuracy, and according to the requirements for the purpose of the product and the characteristics of the parts, they can be divided into the following types:

Classification of coatings according to the basic principles:

1. According to their purpose - protective or corrosion-resistant, heat-resistant, anti-friction, light-reflecting, decorative, etc.;
2. According to their physical or chemical properties - metallic, non-metallic, refractory, chemically resistant, light-reflecting, etc.;
3. According to the nature of the elements - chromium, chromium-aluminum, chromium-silicon, etc.;
4. According to the formation of the surface layer - alumina, silicide, boride, carbide, etc.

Coatings are divided into the following types by thickness:

less than 1 micrometer, thin film (ultrathin);

1÷10 micrometers, very thin;

10÷40 micrometers, micro thin;

40÷300 micrometers, mill thin;

300÷1000 micrometers, thin;

1÷3 millimeters, medium thickness;

3÷8 millimeters, thick;

More than 8 millimeters, very thick.

Coatings are also classified according to their ability to bond strongly to the base. In this case, the strength of the bond or bond formation between the coating and the material, that is, the main property of the composite, $\sigma_{сб}$, is taken into account. This depends on the contact surface of the two adjacent units. When determining the characteristics of the coating, the strength of the bond of the coating σ_{c6} is compared with the strength of the bond of the material σ_{60} and the strength of the coating σ_{61}. In connection with this, the possibilities of increasing the strength of the bond of the coatings with the base were considered.

As shown in Figure 2, when preparing a solar oven device, it is first necessary to bring the metal sheet into a parabolic shape. Then, the main goal of cleaning the surface of the material from various impurities is to smooth the surface of the material and clean it from various foreign rocks. The metal surface of the device base is made of hard special-purpose thin steel, and the surface should be well cleaned and smooth without any irregularities.

The height of the support supporting the parabolic base should be appropriate for the dimensions of the device, but not less than 1 m. In cases where the height of the support is less than 1 m, a number of inconveniences arise when working with the device. The parabolic base is divided into 6 parts, and the surface of each part is treated separately. After completing the cleaning and assembly process, the surface roughness is normalized using polyester putty in order to fill the voids and at the same time normalize the level of depressions. Then, the optical part was made of small-sized mirrors of the waste type. In this case, the mirrors were made with 6 facets of the same size, Figure 3. This shape is considered convenient and effective in directing light to a common focus when the facets are assembled on a parabolic base compared to other shapes.

a) The process of technical processing of the surface of a paraboloid-shaped solar concentrator

b) The process of coating the open slots of the paraboloid-shaped solar concentrator is presented.

Figure 2. Mechanism for cleaning the surface of starting materials in the preparation of a solar furnace device. a)

Figure 2-a) shows the base of a paraboloid-shaped solar concentrator. To prepare this base, it is first cleaned of various dust and debris. It consists of 6 surfaces, which when combined form a circular paraboloid. The main purpose of creating small surfaces of this type is to make mechanical processing of the surface, grinding of surfaces, and finishing work easy and convenient.

Figure 2-b) shows the basis of a fiber paraboloid-shaped solar concentrator. During the process of joining the surfaces, it is observed that small gaps remain open at the edges of the surfaces that do not match each other. Such gaps have a negative effect on the location of the mirrors, and together with this, they lead to a violation of the focal length. This situation indicates that the location of the mirrors is uneven. Therefore, work is carried out to close the remaining gaps and smooth the surfaces.

a)The appearance of a 6-sided mirror

b)130 pieces of 6-sided mirror appearance

Figure 3. 6-sided mirrors with sides of 60 mm

The finished facets are attached to the parabolic-shaped base using special adhesives. When attaching the facets, it is necessary to pay special attention to the fact that their sides are equal to each other and are located correctly, since the error in gluing one facet increases in the placement of subsequent facets according to the law of arithmetic progression. These errors are a significant obstacle to achieving the expected results from the device. It is advisable to start gluing from the center of the parabolic base and fill the sides of the hexagon.

All parameters of the solar furnace device were calculated. The initial experiments began in the second half of March. We took into account the normal weather of the day of the experiment, the times of sunrise and sunset, and the hourly change in the thermal energy accumulated in the concentrator. We entered the results of each day on the basis of special tables and graphs. These results are important for obtaining the necessary conclusions and results in the subsequent experiments. We can learn from these experiments that the results on sunny, cloudy and rainy days of the weather are very different from each other. The thermal energy accumulated in the focus shows different temperatures in three parts of the day. The results in the second half of the day gave higher indicators than the results in the morning and sunset. According to the results of our initial experiments, due to the lower temperature of sunlight in March, the thermal energy accumulated in the concentrator focus appeared at a slightly lower temperature than we expected. The results obtained on sunny days of the month of Matr show that the temperature increased by about 50^o C throughout the day and decreased suddenly in the middle of the day. We can see that the temperatures of sunny days are fundamentally different from each other, and the temperatures increase every hour. However, a sudden decrease in temperature was observed from the middle of the day. Let's get acquainted with the results obtained on sunny days of the Bokhor season. Figure 5 shows the results obtained in March. The temperature began to increase from the beginning of April, which is 400-550^{0}C higher than the result in March (Figure 6). Figure 7 shows the result of a small-type solar furnace on a sunny day in May. From Figure 7, we can see that the temperature at the focus of the small-type solar furnace reaches a high result in the second half of the day. The temperature in the furnace is 1600^o C, which makes it possible to weld and melt any materials that can melt at this temperature, as well as to shape them into various shapes.

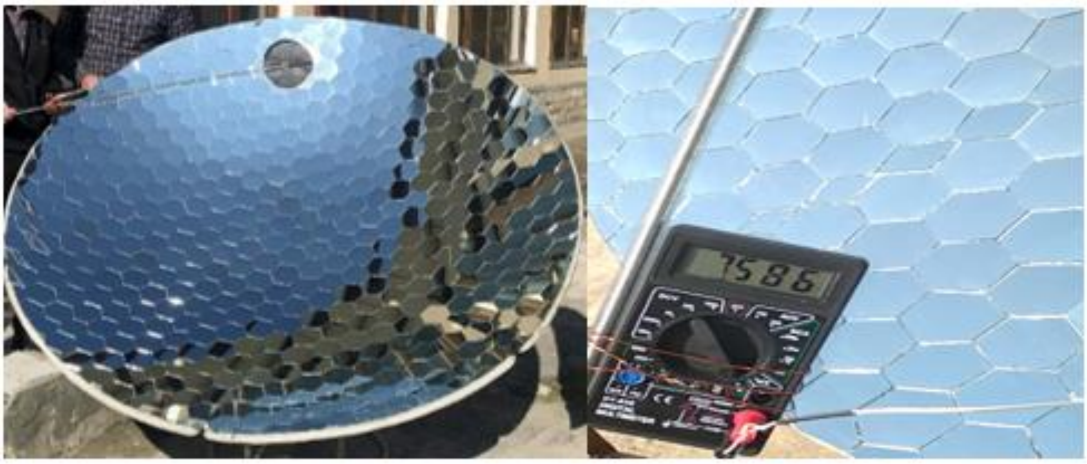

Figure 4: Small type of solar oven

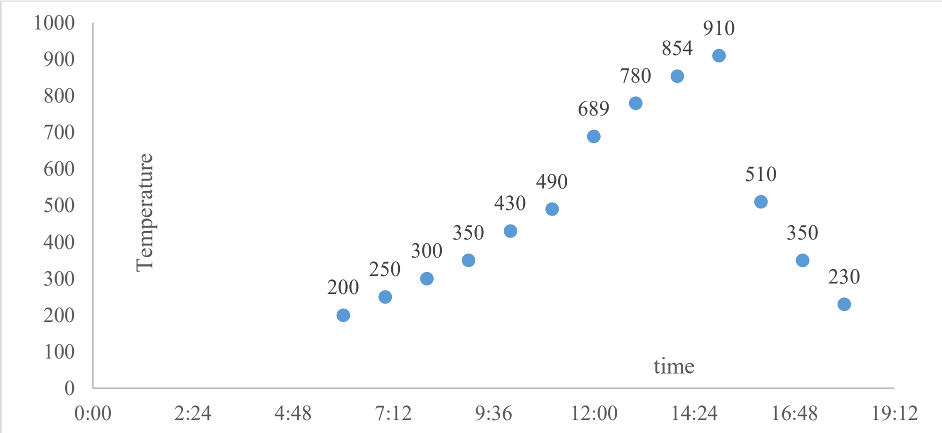

Figure 5. One-day results of a small-scale solar oven on a sunny day in March

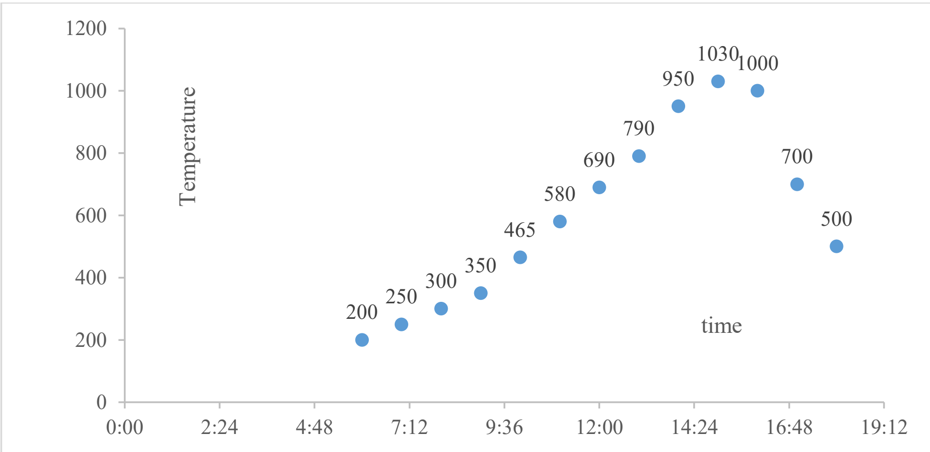

Figure 6. One-day results of a small-scale solar oven on a sunny day in April

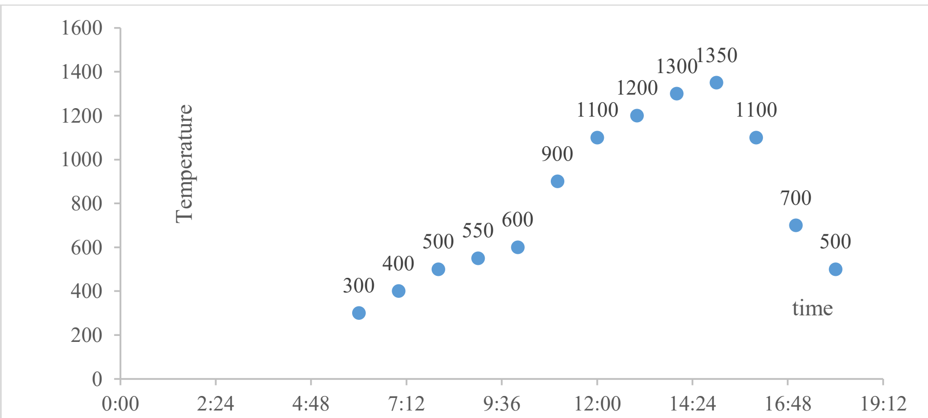

Figure 7. One-day results of a small-scale solar oven on a sunny day in May

CONCLUSION

In conclusion, various coatings can be used for the solar furnace device, but in our work we selected and used coatings with high optical parameters. The materials used for the base of the solar furnace are required to have slow hardening properties, because during the manufacture of our structure, it is necessary to position the mirrors in a position that determines the concave surface and the point of intersection of the rays, that is, the focus, and this takes a certain time. Taking this into account, we found it advisable to use coatings that exhibit hardening properties within a certain time. Considering that the reflectivity (optical) properties are higher than other materials, we used mirrors. The temperature at the focus of a small solar furnace is 1500°C, which allows re-casting materials up to 1500°C. The solar furnace can be used for thermal treatment and welding of high-temperature materials, metals, and polymers. This will increase the use of environmentally friendly energy sources in the future and ensure that natural resources reach future generations.

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