Pre- Calculation of The Accuracy of Geodetic Works During Installation And Adjustment of Solar Furnaces

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Abstract

This article proposes a theoretical analysis of the geometry of the formation of solar precision geodetic works to ensure the installation and alignment of solar furnace elements. The main processes are determined, the errors that are made that affect the efficiency of the solar furnace.

Keywords — *solar oven, solar energy, concentration, sun stream, adjustment of salt furnaces, focal image of the sun, mirror paraboloid, apparent angular diameter, parabola opening angle, flare stain.*

I. INTRODUCTION

The Sun is considered as one of the energy, sources that can play a significant role in the development of the economy separate the territory of the world, especially in areas with a large number of clear.

But, flux density solar radiation from the Earth`s surface relatively high and do not provide obtain the temperature of the necessary to solve important scientific and engineering problems such as made of high-process.

Technological problem getting over the net materials and alloys, Ray welding can successfully solved using mirror concentrating systems (MCS).

Solutions this task includes a number of problems, and in particular, observations shape and size of individual elements and all complex as a whole, the accuracy of them in the winter location and orientation.

II. RELATED WORKS

The main purpose of the solar high-temperature furnace is to collect a certain amount of solar energy and concentrate it on a small area. The concentration is carried out by focusing the flow of sunlight.

The power of the solar furnace is estimated by the achievable value of the temperature obtained in the focal plane.

The value of the maximum achievable temperature for an ideal solar concentrator can be calculated by the formula [1, 2].

$$T_F^{HD} = \sqrt[4]{\frac{E_F^{HD}}{G_0}} \quad (1)$$

Where $G_0 = 5.672 \cdot 10^{-8} \frac{\text{Вт}}{\text{м}^2}$, K4 constant Stefana – Bolsmana

$$E_F^{HD} = R_S \frac{1.2}{\varphi_0^2} \sin U_m E_0$$

E_F^{HD} - irradiation in the focus of an ideal solar concentrator;

R_s - integral transmittance (specular reflection) of the system; φ0 - angular radius of the Sun, equal to 0.004654 rad.; E_0 – is the density of direct solar radiation; U_m - the opening angle of the concentrator.

Calculations show that in the focus of the described furnace it is possible to obtain a maximum temperature up to 4940°C. However, in the focus of the real concentrating system, irradiance will be less($E_F < E_F^{HD}$), since the mirror reflection coefficient RS < 1 and there are losses due to non-compliance with the geometry of the system. The results of measurements of the temperature of the solar furnace showed that the actual temperature in the focus of the concentrator reached 2750°C.

According to the above data, it can be seen that the temperature loss is mainly a consequence of technological tolerances for the manufacture of reflective mirror surfaces.

Consider one of the variants of the approach to the appointment of the accuracy of geodetic works during installation, Assembly and adjustment of the solar furnace (SP). To do this, we analyze the geometry of the formation of the focal image of the Sun in the ideal manufacture of SP.

It is known that when designing a joint venture, its dimensions and characteristics are determined mainly by a given value of the flux density in the focal spot.

Imagine a perfect mirror paraboloid (its axial section), directed its axis at the "fixed" Sun. In this case, each point (Xi , Yi) of the parabola forms in its focus an image of the Sun with a visible angular diameter α =32'.

The linear diameter of the image of the Sun in the plane passing through the focus of the parabola perpendicular to the direction of the beam reflected by the parabola from the center of the Sun (Fig.1) is calculated according to the formula

$$d_i = 2\left(\frac{P}{2} + Y_i\right) tg\frac{\alpha}{2} \quad (2)$$

Since, ultimately, the image of the Sun should be obtained in the plane of the focal diameter of the paraboloid, calculate the parameters of the focal sun spot.

On the basis of Fig.1 have:

$$FB = \frac{d_i \cos\frac{\alpha}{2}}{2\cos\left(\beta_i - \frac{\alpha}{2}\right)} \quad ; \quad FC = \frac{d_i \cos\frac{\alpha}{2}}{2\cos\left(\beta_i + \frac{\alpha}{2}\right)} \quad ,$$

(3)

Where

$$\beta_i = arctg\frac{X_i}{P/2 - Y_i} \quad (4)$$

Substituting in (2), (3), (4) the coordinate values for points 1 (parabola vertex) and 2 (as far as possible from the parabola axis) for the created joint venture we get:

d1 = 55.8 mm FB = 62.2 mm β2 = 54 ° 12.7'
d2 = 73.2 mm FC = 63.0 mm

Having performed similar calculations for point 3 to a symmetric point 2, we obtain:

FB3 = 63.0 mm, FC3 = 62.2 mm.

According to the above data, it can be seen that in the focal plane the image of the Sun, obtained from points 2 and 3, has the form of an ellipse with the dimensions of a minor axis of 36.6 mm and a large one - 63.0 mm.

Similar calculations were performed for points of a parabola characterized by its opening angles - β, given through 10 °.

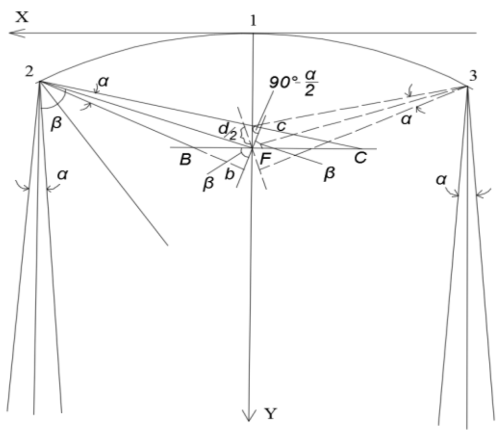

Fig. 1. To determine the linear diameter of the image of the Sunon the focal plane of the hub

With some approximation, the same results can be obtained by formulas.

$$a = \frac{d_i}{(1+\cos\beta)\cos\beta}; \quad b = \frac{d_i}{1+\cos\beta}, \quad (5)$$

Where a, b are the values of the major and minor semiaxes of the ellipse, respectively;

β is the angle of a parabola formed by its optical axis and the axial reflected beam.

The results of the calculations are shown in Table 1 and illustrated in Fig. 2.

From Fig. 2 it follows that the focal spot of an ideal paraboloid has a maximum concentration (number of overlaps) in the central zone with a diameter of 55.8 mm.

The expansion of the spot along the minor axis to 36.6 mm is a consequence of an increase in the distance between the focus and a point on the surface of the paraboloid, whereas the spot ellipticity with a 63 mm major axis is a consequence of the increase in distance and oblique incidence of the beam on the focal plane.

TABLE I
The results of calculations of the parameters of the focal sunspot spot

The angle between the optical axis of the parabola and the reflected beam, $\beta°$	Ellipse big axis a, mm	Ellipse minor axis b, mm	Ellipse area S, mm	The ratio of the area of the ellipse. Smin / Stek
0	27,9	27,9	2445,4	0,97
10	28,5	28,1	2515,9	0,88
20	30,6	28,8	2768,6	0,75
30	34,5	29,9	3240,7	0,60
40	41,2	31,6	4090,1	0,52
50	52,8	34,0	5639,7	0,43
60	74,4	37,2	8694,9	0,28

According to Table 1, it can be seen that the density of the solar flux in the focal spot formed by different parts of the concentrator is not the same. The flow density from the peripheral points of the concentrator is 4 times less than from the central ones.

Calculate the value of the mean square error of the total adjustment of the solar furnace.

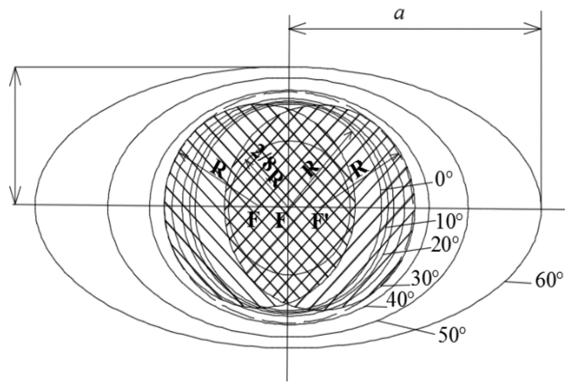

Fig. 2. Formation of the image of the Sun in the focal plane of the hub

Taking the total mean square random error m_R of all processes of installation, manufacturing and alignment of solar furnace elements equal to one third of the radius - R minimum focal spot, which is equivalent to the displacement of the center of the focal spot, we obtain a decrease in the area of maximum concentration to the value $S = \left(\frac{2}{3}R\right)^2 \pi$.

In this case, the flux density in the focal spot will be redistributed and, consequently, the effective temperature of the solar furnace will decrease.

Since the size of the reduced focal spot is added by n facets, the value of the expectation of the center of its grouping will be equal.

$$M_R = \sqrt{\frac{m_R}{n}} \quad (6)$$

From here, with a confidence level of 0.997 (significance level t = 3), we find that the value of the expectation of the grouping center of the reduced focal spot or the expectation of its radius is in the range.

$$\frac{2}{3}R - M_R \cdot t \le \frac{2}{3}R \le \frac{2}{3}R + M_R \cdot t$$
(7)

Conversion of linear magnitude mRto angular in azimuth or angle of inclination is performed by the formula

$$m_{A,V} = \frac{m_R}{R} \cdot \frac{\alpha}{2} \quad (8)$$

Where α is the apparent angular diameter of the Sun:

Hence, the total angular mean square error of all processes of installation and alignment of elements of the solar furnace is equal to

$$m_u = m_{A,V} \cdot \sqrt{2} \quad (9)$$

For the considered solar furnace, the values calculated by the formulas obtained will be equal to M_R = 9.3 mm, S = 1086.3 mm2, M_R = 0.13 mm, 18.2 mm ≤ 18.6 mm ≤ 19.0 mm, $m_{A,V}$= 5.3' m_u = 7.5'.

Consider the errors of manufacture and adjustment of the main elements of the joint venture, of which the total error of the adjustment.

Since the joint venture consists of many elements, in principle, the total error should be determined by the values of the components, which can be divided into two groups: technological errors and geometric random errors.

The first group includes the errors that arise due to the imperfection of the technology of manufacturing structures and elements of the joint venture. They cannot be excluded directly by geodetic methods and means, although it is possible to measure deviations. These include:

1. The errors of the manufacture of reflective surfaces of the heliostats and hub.
2. Non - perpendicular axis of rotation of heliostats.
3. Error setting azimuthal axes of heliostats in the vertical position.
4. The errors of manufacturing the carrier frame of the hub.
5. The torsion error of the direction sensor.
6. Error deformations of mirrors and metal structures of heliostats under the action of weight, temperature and other loads.
7. The errors caused by deformations of the bearing frame hub.

Geometric random errors occur during the installation of the technological equipment of the joint venture and during its operation, which may vary in time under the influence of external factors. Their values can be adjusted in the process of geodetic measurements.

It is expedient to refer to them:

1. Error adjustment of the heliostat facet.
2. The errors of orientation (installation) of direction sensors.
3. The error tracking sensor direction.
4. Errors of installation (assembly) of the fatt on the base frame of the concentrator (formation of a reflecting surface).
5. Orientation errors facet concentrator.

As can be seen from the above list, some technological errors are excluded at the same time by correcting geometrical random errors. In particular, in the process of carrying out adjustment work, the errors of manufacturing the support frames of the heliostats and the hub are automatically corrected.

Based on this, it can be assumed that the total error of the joint venture is composed of the following main components:

1. The errors of the manufacture of the reflective surface of the concentrator facet – $m_{ik.}$
2. The error of deformation of the metal structure of the concentrator under the $m_{ik.}$.of weight, temperature and other loads – $m_{d.k1}$.
3. Error deformations of the concentrator mirrors – $m_{d.k2}$.
4. The errors of installation (assembly) of the fatt on the base frame of the concentrator (the formation of a reflective surface) – m_{cb}.
5. Orientation errors (adjustment) concentrator facet – $m_{u.k.}$
6. The errors of the manufacture of the reflective surface of the heliostat facet – $m_{i.g}$.
7. The errors of deformations of the heliostat metalwork under the action of weight and other loads - $m_{d.\ g1}$.
8. Errors of deformations of the heliostat mirrors - $m_{d.g2}$.
9. Alignment errors of the heliostat facet – $m_{u.g.}$
10. Orientation errors of direction sensors - $m_{or.}$.
11. Error tracking direction sensor - $m_{c.\ d.}$
12. Torsion error of the direction sensor - $m_{k.d.}$

Consequently,

$$m_u = \sqrt{\begin{gathered} m_{i.k}^2 + m_{d.k1}^2 + m_{d.k2}^2 + m_{cb}^2 + m_{u.k}^2 \\ + m_{i.g}^2 + m_{d.g1}^2 \\ + m_{d.g2}^2 + m_{u.g}^2 + m_{or}^2 + m_{c.d}^2 + m_{k.d}^2 \end{gathered}}$$

Taking in the first approximation, the principle of equal influences, i.e.

$$\begin{aligned} m_{i.k}^2 = m_{d.k1}^2 = m_{d.k2}^2 = m_{cb}^2 = m_{u.k}^2 = m_{i.g}^2 = m_{d.g1}^2 \\ = m_{d.g2}^2 = m_{u.g}^2 = m_{or}^2 = m_{c.d}^2 \\ = m_{k.d}^2 = m_0 \end{aligned}$$

will get

$$m_u = m_0\sqrt{12}$$

from here

$$m_0 = \frac{m_u}{\sqrt{12}} = \frac{7{,}5'}{\sqrt{12}} = 2{,}2'.$$

Thus, the standard error of each of the listed components should not exceed 2.2 '.

III. CONCLUSIONS

The results of the analysis of the work of modern solar energy concentrators led to the following conclusions:

1. Based on the analysis of the geometry of the image of the Sun in the focal plane of an ideal paraboloid substantiates the most general approach to the appointment of the accuracy of the execution of the manufacturing processes, installation and alignment of solar furnace elements.

2. Identified the main processes, the error of which affect the efficiency of the joint venture and reduce its capacity.

3. The total root mean square error of all is counted manufacturing processes, installation and quotations of elements of the joint venture and its components.

4. It is shown that increasing the power of the solar furnace is possible due to an increase in the flux density in the focal spot; it is possible to approximate the size and density distribution to the ideal only using geodetic methods of mounting control and alignment of the concentrator, heliostats and tracking system.

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