THE METHOD TO DECREASE ERROR OF CHIMNEYS DEFORMATION MEASURING UPON CONTINUAL REFLECTOR LESS INCLINED MEASURING USING TOTAL STATIONS

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Abstract

In the article the suggested method to decrease error of chimneys deformation continual inclined measuring using total stations is described. It is determined that upon continual inclined reflector less measurements of chimneys deformation in power industry the most significant factors causing error of inclined measurements are angle of beam incidence, duration of measurements series, beams propagation. The method for forming and further accounting of equally distributed on time systematic error of measurements of chimneys inclination by way of synthesis of special order for organization of measurements using total station is suggested. The mathematical basics of the method is described.

Keywords: chimney, deformation, measurements, total stations, error.

I. Introduction

It is well known that the non-reflector mode of total station measurements, having a fairly high speed of execution, is characterized by a much larger error compared to the measurement mode using prismatic reflectors [1-4].

As noted in the work [1], the principle of operation of an electronic total station in the non-reflector mode does not differ from the mode of operation of a conventional total station, where the measurement of the oblique distance to the object, as well as two angles (horizontal and vertical) allows you to determine the coordinates of the point under study. The angle of incidence, the type and color of the reflecting surface significantly affect the energy of the reflected beam, and hence the accuracy of the measurements. Another, no less important factor affecting the accuracy of remote measurements is the coincidence of the direction of the total station beam with the direction to the Sun. So, for example, according to [1], a distance of 30 m is measured with an error of 0.228 mm if these directions coincide and 0.2098 mm if they do not coincide, i.e. directions are opposite.

According to the work of [2], the measurement range of electronic total stations in non-reflector mode in some new devices reaches 1500 meters for white reflective surfaces or several hundred meters for dark ones. At the same time, according to [3], the cost of non-reflective measurements is only 5% of the cost of reflective measurements. As for the possibilities of compensating for errors arising in this mode, when studying the absolute displacements of distant objects, systematic errors are mutually compensated. In addition, repeated measurements can significantly reduce the random component of this error.

II. Methods

As noted in the work [4], the above factors can significantly affect the results of assessing the verticality of heat pipes of power facilities, measured using electronic total stations in the non-reflector mode (Fig.1).

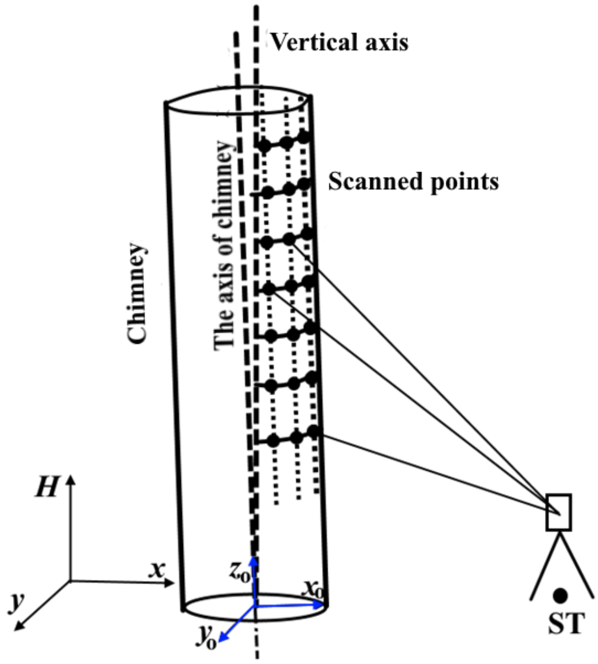

Fig.1: *Scheme for measuring the verticality of heat pipes of power facilities using an electronic total station in a non-reflector mode.*

As noted in the work [4], according to the European EUROCODE standard, the maximum allowable deviation of heat pipes with a height of H_d is determined by the formula.

$$\Delta[m] = \frac{H_d[m]}{1000} \cdot \sqrt{1 + \frac{50}{H_d[m]}} \tag{1}$$

According to [4], the joint use of the Leica TS30 total station and the Riegl Vr-400 laser scanner makes it possible to determine a cloud of points on the surface of an object and model them geometrically on a certain coordinate system. Further model calculations carried out using the appropriate Matlab program allows you to determine the inclination of the heat pipe. Without going into the algorithmic and software of such calculations, we note that according to the data given in [4], the accuracy of determining the slope of the heat pipe in this method depends significantly on the number of studied points on the surface of the object.

The foregoing actualizes the issue of developing special methods to compensate for the effect of battery discharge on the measurement error. Further in this section, we consider the question of finding such an optimal procedure for conducting a long-term series of total station measurements in which it would be possible to synthesize a systematic error uniform in time in the form of the sum of errors due to the angle of incidence of the beam and also due to battery discharge, due to the choice of a special time sequence of oblique measurements. The corresponding scheme of measurements is show in Fig.2.

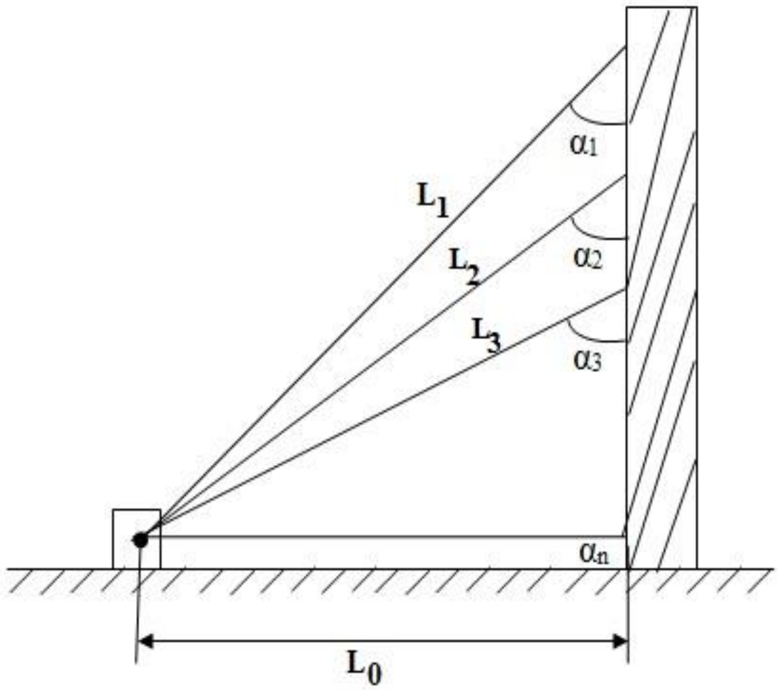

Fig. 2: *Scheme of performing compensated multipoint measurements of chimney deformation.*

III. Results

It is determined that when carrying out long-term non-reflector total station measurements of the inclination of heat pipes of power facilities, the most significant factors leading to the appearance of inclination measurement errors are the angle of incidence of the beam, the duration of a series of measurements and the path of the beam.

A method is propose for the formation of a systematic error of measurements of the inclination of a heat pipe, uniform in time, by synthesizing a special procedure for organizing total station measurements, followed by taking into account the systematic error. The mathematical substantiation of the proposed method is given.

IV. Discussion

This fact is well illustrate in Figure 1, where it is seen that the mean square error of the calculation result decreases almost exponentially with an increase in the number of measurement points in the range of $10^4 - 10^5$ estrus.

The work notes [4] that this error arises due to such reasons as different angles of incidence of the laser beam on the surface of the object, non-uniformity of the reflective properties of the surface, and also due to the meteorological factor, which consists in a rather significant increase in temperature over the time period of multipoint measurements. The corresponding change curve for a period of four hourly measurements is shown in Fig.4.

At the same time, it is well known that when carrying out such long-term series of measurements, measures must be taken to eliminate the effect of the influence of the discharge of the battery of meters on the measurement result. As shown in the work [2], the effect of discharging the total station battery can lead to measurement errors reaching several millimeters at a distance of 8.5m.

The corresponding curve of dependence of the measurement error due to the effect of battery discharge on the duration of the measurement series is shown in Fig.5. [2].

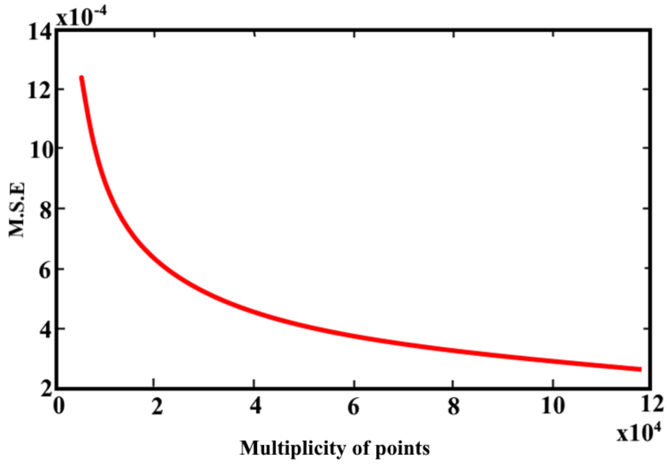

Fig.3: *Curve of dependence of the error in determining the slope of the heat pipe on the number of measured points on the surface of the object [4].*

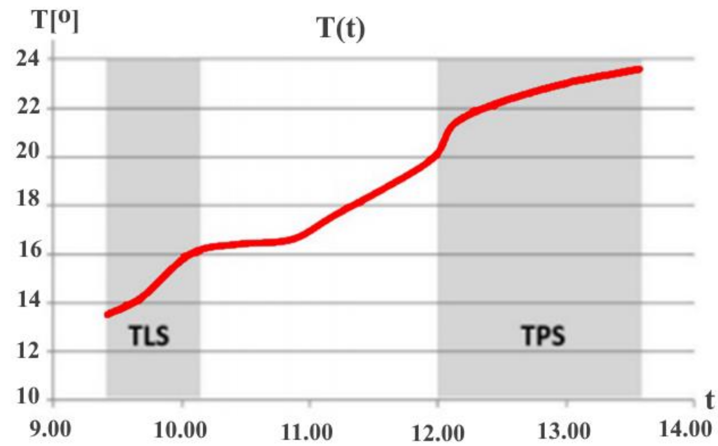

Fig. 4: *Graph of temperature changes up to a period of four hourly measurements of the positions of points on the surface of the heat pipe in the number of 105 units [4].*

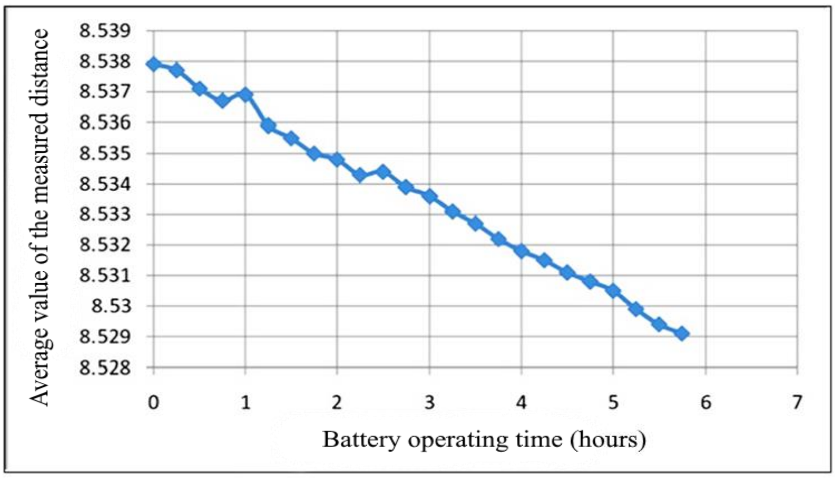

Fig. 5: *Graph of the change in the measurement error of the distance to the object with an electronic total station at a distance of 8.5 m, depending on the duration of the series of measurements.*

We assume that there are the following causes of measurement error:

1. Current time – *t*
2. The angle of incidence of the beam on the surface of the pipe – α
3. Different beam distances – *L*

Because L_i and α_i are interdependent, we denote the angles of incidence as

$$\alpha_i = 90^\circ - arccos\frac{L_0}{L_i} \tag{2}$$

In general, we write

$$L_i = \varphi(\alpha_i) \tag{3}$$

Therefore, the total error Δ_0 can be written as a function depending on two arguments, *t* and α.

$$\Delta_0 = f(t, \alpha) \tag{4}$$

We write the total differential (4) as

$$d\Delta_0 = \frac{\partial f}{\partial t}dt + \frac{\partial f}{\partial \alpha}\partial\alpha \tag{5}$$

If we take into account that the change in the argument α occurs on the scale of the current time, then we write

$$\alpha = \varphi(t) \tag{6}$$

From (6) we get

$$d\alpha = \varphi^{'}(t)dt \tag{7}$$

Taking into account (7) in (5) we write

$$d\Delta_0 = \frac{\partial f}{\partial t}dt + \frac{\partial f}{\partial \alpha}\cdot\varphi^{'}(t)dt = [k_1 + k_2\varphi^{'}(t)]dt \tag{8}$$

where $k_1 = \frac{\partial f}{\partial t}; k_2 = \frac{\partial f}{\partial \alpha}$

Integration (8) within $t_{min} \div t_{max}$ gives

$$d\Delta_{0\ int} = k_1 \cdot dt + k_2[\varphi(t_{max}) - f(t_{min})] \tag{9}$$

From expression (9) under the condition

$\Delta_{0\ int} = 0$

We get:

$$\varphi(t_{max}) = \frac{k_2\varphi(t_{min}) - k_1\Delta t}{k_2} = \varphi(t_{min}) - \frac{k_1}{k_2}\cdot\Delta t \tag{10}$$

Since, by definition, k_1 and Δt are positive values, and k_2 is a negative value, then with the growth of Δt, the value of $\varphi(t_{max})$φ should increase. From heuristic considerations, it is clear that dependence (10) in the real case can be implemented if the following inequality is satisfied

$$\varphi(t_{min}) < \varphi(t_{max}) \tag{11}$$

or, taking into account (6),

$$\alpha(t_{min}) < \alpha(t_{max}) \tag{12}$$

Thus, if we take $\varphi(t_{min}) = \alpha_0$ we write expression (10) as

$$\varphi(t_{max}) = \alpha_0 + \left|\frac{k_1}{k_2}\right|\Delta t \tag{13}$$

Thus, as is clear from expression (13), in order to mutually compensate for the influence of the above two factors, at the beginning of a series of total station measurements, one should examine the points located on the upper zone of the heat pipe, gradually decreasing in the direction of increasing the angle α. Thus, a large error due to a small beam incidence angle at the beginning of the measurement interval will be summed up by a small error arising from battery discharge, and vice versa, a small error due to a large beam incidence angle at the end of the measurement series time will be summed up by a large error due to-for battery drain.

Thus, the resulting sums can be considered as systematic components of the error and can be taken into account in further processing of the calculation results.

Thus, the fundamental possibility of organizing serial long-term measurements of the deformation (slope) of the heat pipe of power facilities with compensation for a specially formed systematic measurement error is shown.

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