OPTIMIZATION PROBLEMS OF PHOTOGRAMMETRIC METHOD OF HYPERBOLIC COOLING TOWER MEASUREMENTS

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ABSTRACT:
In dependence on possibilities of signalling and on univocal identification of observed and control points on external surface of reinforced concrete cooling tower, there are shown advantages and disadvantages of monophotogrammetric method in comparison with stereophotogrammetric method.
There are shown some examples of graphic results presentation by means of own and commonly accessible packages of computer programs.

KEY WORDS: Cooling towers, Deformation measurement, Photogrammetry.

1. INTRODUCTION

Reinforced concrete cooling towers which belong to the biggest engineering thin-walled structures, because of their geometric shape (mainly because of relation between shell thickness to its diameter) need constant macroscopic inspection and shell deformation investigation, because of industrial aggressive atmosphere influence and also constant surface wetting (Chauvel at all 1990, Golczyk 1989, Owczarzy 1989, Owczarzy 1991).

Detailed investigations about reasons of almost ten collapses of reinforced concrete hyperboloid cooling towers, which took place since 1965 in Great Britain, France and Poland, did not several one immediate cause of disaster.

In reasons' analyses of not only collapses of cooling towers but also minor impairments, there are emphasized, apart from external factors, mainly very strong wind pressure with variable velocity, the realization imperfections and exploitation mistakes (Golczyk 1989, Owczarzy 1989). Effects of these incorrectnesses are phenomena:
- concrete degradation because of lack of maintenance and preservation repairs;
- residual and dynamic deformations of the shell.

Evaluation of shell's stability and strength is carried out to determine the cooling towers' state of safety and exploitation reliability, taking into consideration the investigations' results of above mentioned phenomena. Mostly applied is the method of finite element with taking into account the geometrical and physical shell's imperfection. A net of finite elements is generated on shell's surface which theoretical shape is one sheet axially symmetric hyperboloid. Values of geometrical and physical imperfections are assigned to node lines, but inside the net, these values are linearly approximated. The geometrical imperfection values in the finite element net taken from geodetic or photogrammetric measurements results.

After cooling tower collapses, mainly in Great Britain and France, there was determined the range of cyclic geodetic and photogrammetric measurements of all remaining cooling towers. At the first stage, there are carried out the measurements of real shape of shell outer surface with simultaneous record of all injuries and defects in shell using photographic, photogrammetric and thermovisional technics. During subsequent inspection measurements carried out in the aim to record the injuries' and defects' alterations, there are used the same measurement method, with particular consideration of photogrammetric method. Besides photogrammetric methods, there are also used for cooling tower shape investigations some special geodetic system e.g.: measuring system Wild Leitz ATMS - automatic theodolite measuring system, which permits to determine, with a great accuracy, an unlimited quantity of unsignalled points on cooling tower surface without application of reflectors (Katowski, 1990).

2. PHOTOGRAMMETRIC METHODS TO DETERMINE GEOMETRIC IMPERFECTIONS

Collapse of a cooling tower at power station in Turoszów, Poland, 1987, caused greater interest in technic state of all remaining towers in Poland. Determination necessity of real shape of cooling towers external surface contributed to elaboration of new methods or taking advantage of existing ones, which permit to get the data for evaluation of investigated objects stability. These methods can be divided in two groups: monophotogrammetry and sterephotogrammetry. Each of these methods has its advantages and disadvantages, which may be essential according to the measurement purpose, art of geometric imperfections or possibilities of check-up points' signalling on cooling tower surface.

2.1 Monophotogrammetry method

Monophotogrammetry method used to investigation of rotation surface shapes, is based on conic sections method which, in classical solutions, is used to determine the approximation parameters of a hyperboloid and inclination of geometric axis.

When applicating monophotogrammetry, the conic sections method (surrounding tangents' method) is used to the shape investigation on planes which contains the tangency points of radii connecting projection center which cooling tower surface (Woźniak, 1988).

At the first stage of investigations, there is to be determined the real and theoretical shape of cooling tower external surface on ground of photogrammetric pictures, taken from camera stands surrounding the tower. Theoretic shape of rotational hyperboloid surface at the plane containing tangency points of observation radii from a given stand differs according to coordinates of projection center $S(x_0,y_0,z_0)$ and to hyperboloid semi-axes $\boldsymbol{a}$ and $\boldsymbol{b}$. General equations of the tangent lines, determining the geometrical intersection point of vectors perpendicular to the tangent direction and vectors tangent to the direction from a given camera stand has the following form:

$$z=\frac{b^2x_0}{a^2z_0}x+\frac{b^2y_0}{a^2z_0}y-\frac{b^2}{z_0} \tag{1}$$

Assuming for each camera stand a local coordinate system $S(0,y_0,z_0)$, equation (1) in projection on plane YZ shows a straight line with an inclination angle ω of the vertical (Fig. 1.).

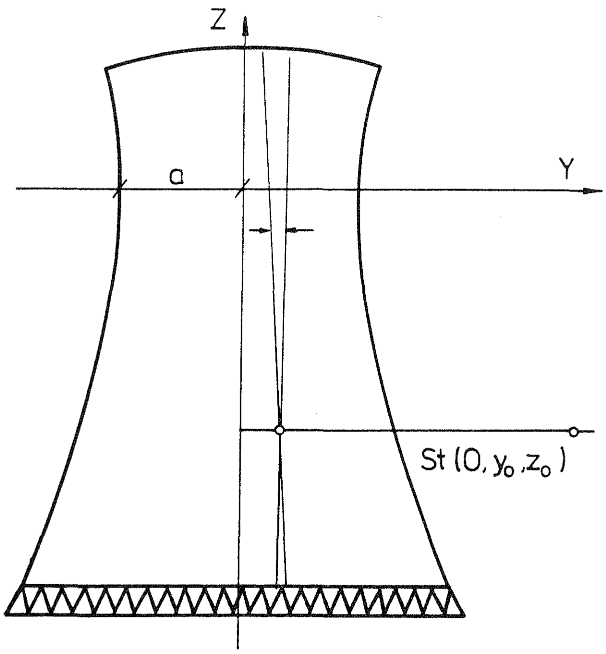

Fig.1. Plane containing tangent points projected on *ZY* plane.

Equation of this straight has the form:

$$z=\frac{b^2 y_0}{a^2 z_0}y - \frac{b^2}{z_0} \qquad (2)$$

Theoretical shape of cooling tower axis, observed from the camera stand $S(0,y_0,z_0)$, projected on the plane *XZ*, is descripted by a hyperbol equations:

$$\frac{x^2}{\frac{a^2(y_0^2b^2-a^2z_0^2-a^2b^2)}{y_0^2b^2-a^2z_0^2}} - \frac{\left(z-\frac{a^2b^2z_0^2}{y_0^2b^2-a^2z_0^2}\right)^2}{\frac{y_0^2b^4(y_0^2b^2-a^2z_0^2-a^2b^2)}{(b^2y_0^2-a^2z_0^2)^2}} = 1 \qquad (3)$$

assuming $z_0 \neq 0$ and $x^2 + y^2 \geq a^2$.

For calculations of the real shape of cooling tower surface along the tangent line from a given stand and for scaling of photogrammetrical model, there is used the determined angle ω, taking into account the given elements of external and internal orientation of the picture. All calculations, taking into consideration the varying shell thickness, are carried out using COOLMONO program, whereas graphic results presentation by means of GRAPHER program. An example of determination result of geometric imperfection, carried out from one stand are shown in Fig.2.
For determination of deformation alterations of cooling tower surface, the real shape of which had been determined during primary measurement, the most frequent applicated is the time parallax method, taking into consideration the scale alterations depending from height of the point observed.

2.2. Stereophotogrammetric method

Determination technology of cooling tower shell external surface shape is most often based on independent models method. Application of this method is possible in the case of univocal identification of points observed on the surface and control points which allow to determine the corrections of elements of external orientations.

Precision analysis of space coordinates determination is carried out taking into consideration the differences of observation points coordinates in strips of model covering and the differences of control point coordinates (Mierzwa 1991). In the aim as to ensure the required precision ± 10 mm of shell shape determination in observation points, the camera stand and control points coordinates should be determined by means of a geodetic method with an accuracy not less than ± 3 mm (Mierzwa 1991). Stereophotogrammetry gives great possibilities of future and easy processing of calculation result, taking advantage of existing packages of computer graphic e.g. SURFER, GRID, GRAPHER ect. When using this programs, one can freely interpolate the coordinates net, adopted for evaluation of stability and strength by means of finite elements method. Application examples of existing programs for calculations and graphics presentation of investigation results are shown in Fig.3. and 4. (Mierzwa 1991, Owczarzy 1991).

3. FACTORS INFLUENCING CHOICE OPTIMUM METHOD

The presented elaboration methods and examples of their applications are characterized by both advantages and also disadvantages which in dependence on cooling towers characteristics can have a decisive influence on choice of optimum method.

The monophotogrammetric method (one-picture photogrammetric method) can be applicated with success to investigations of deformation alterations along determined meridians. The photogrammetric pictures are being taken from the constant cammera stands during each measurement cycle with preservation of identical elements of internal and external orientations. Monomial observation points on one straight are being observed without necessity of their signaling by means of time parallax method. Precision of these determinations is valuated in limits of ± 5 mm. While determinating geometric imperfections using monophotogrammetric method, there occurs the necessity of hyperbola theoretical parameter calculations for each point independence on imperfections' value determined at first calculation stage. It results from variability of scale alteration coefficient, caused by surface irregularities which contains tangential points of observation radii with cooling tower external surface determined by equation (2). In particular case of occurrence of big and differentiated cooling tower surface deformations in parallel planes, the monophotogrammetric method can lead to improper imperfection determination. In spite of difficulties in current formulation of mathematical model while determining the real shape of cooling tower external surface, the reinforced concrete building specialist highly appreciate the result and presentation way, when using monophotogrammetric method.

Stereophotogrammetric method is completely univocal in respect of mathematical model. This method allowed to realize the precision evaluation on the base of measured control points and its considerably simplifies the calculation process. Exactness of determination of real surface shape is contained in limits of ± 10 mm. Difficulties in application of this method occur in case of lack of any signal points especially after overhaul works, when the

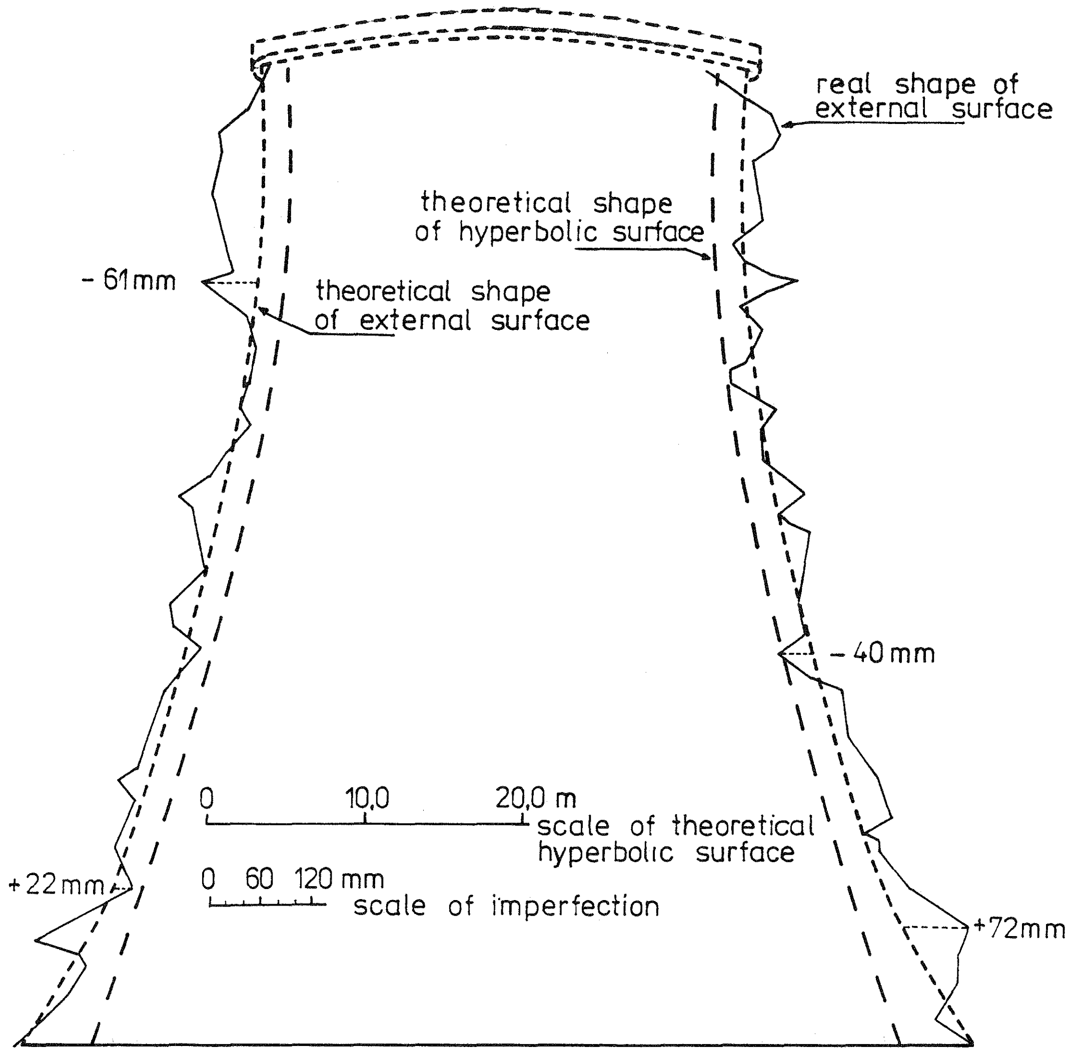

Fig.2. Theoretical and real shape of cooling tower observed from one camera stand.

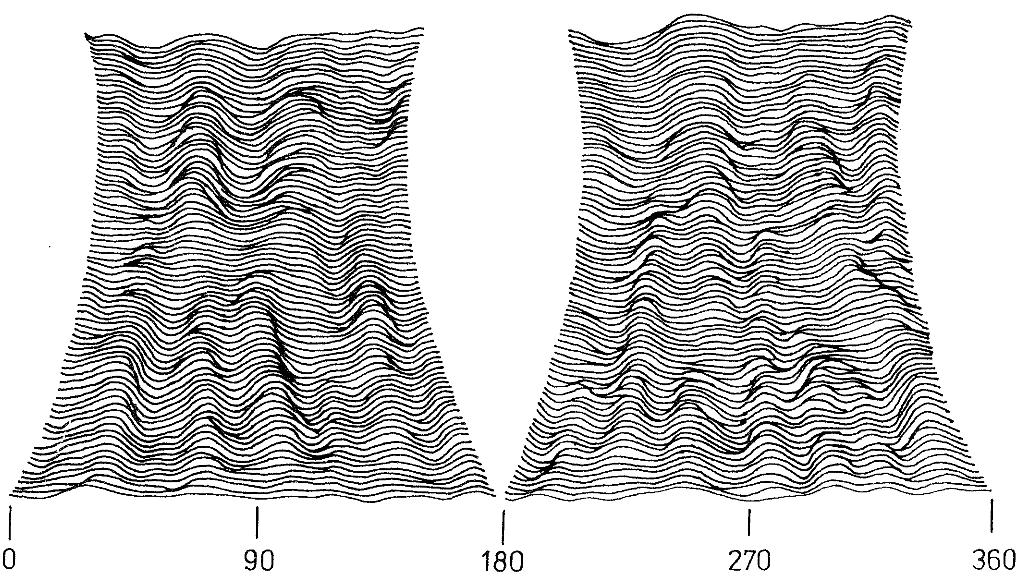

Fig.3. Shell deformation.

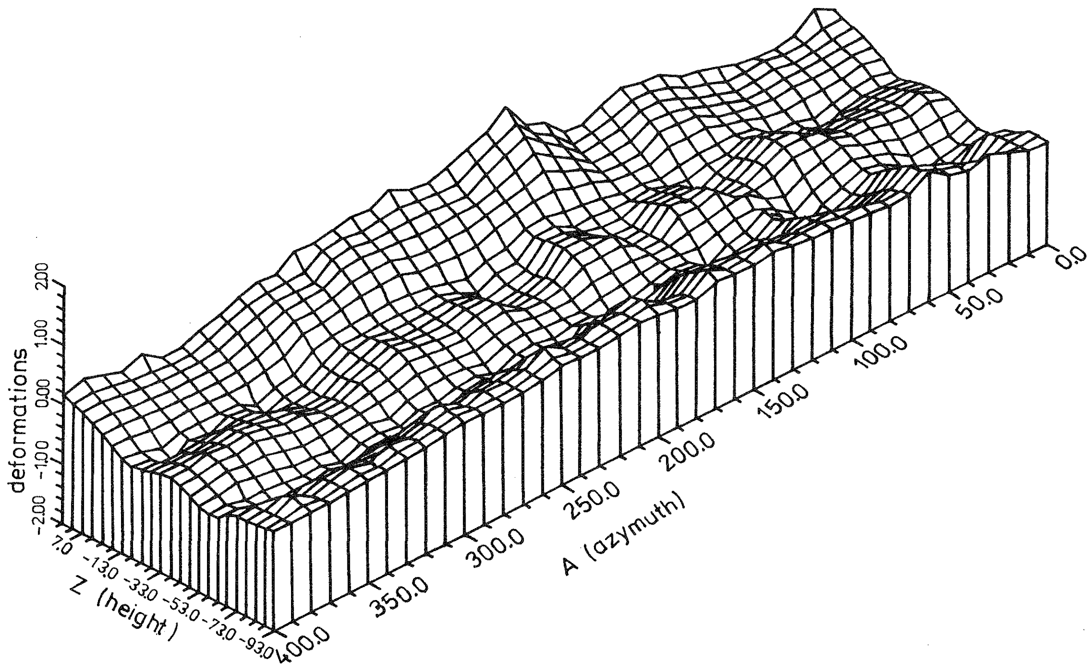

Fig.4. Axonometric view of shell deformation in development.

surface is completely smooth, gunited or painted, or in case of investigation of deformation alterations in time. Determination precision of geometric imperfection alteration in nodes of finite element net , on the base of external surface numerical models, curried out in comparable measurement cycles, can be too small as necessary for univocal evaluation of cooling tower shell stability and strength.

4. CONCLUSION

Choice of one of photogrammetric methods for investigations of real shape of hyperbolic cooling tower external surface depends before all on signalling and identification possibilities of observation and control points on the cooling tower surface. In case of existence of such possibilities, the more suitable method is the stereophotogrammetric one, which also has more possibilities of easy further processing by means of existing computer graphic programs.

In case of cooling towers without possibility of signalling of observation points and control points, and also in investigations of shell deformation alterations, more suitable can prove the monophotogrammetric method. The final choice of the method depend also on possession of photogrammetric devices and on possibility of photogrammetric devices and on possibility of control over adequate computational and graphical programs which permit to determine required values necessary to evaluate stability and strength of cooling tower.

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