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THE PHOTOGRAMMETRIC MEASUREMENTS OF THE SHIP DEFORMATIONS

Abstract

Comprehensive studies in 1974-1979 on five ship hulls at various construction stages were carried out. The hull behaviour under the influence of daily temperature changes in the surroundings and a ship launching was studied.
In these studies a special measurement method was succesfully used, which was a photogrammetric version of so-called constant-plane method well-known in the geodetic engineering.

1. Introduction

Photogrammetric survey methods have succesfully been used recently in Poland to solve certain survey problems concerning the shipbuilding industry.

One of the most interesting examples of the application of these methods is the testing of the ship's hull deformations arising on the stocks.

Herein there are reported complex studies made by the author in 1974-1979 on five ship hulls at various building stages beginning from the erection on a building ship to the final fitting out after the launching.

The hull behaviour under the influence of two main deformation factors was studied. The factors were daily temperature changes of the surroundings /especially due to insolation/ and the ship launching.

In general, the measuring method used herein utilizes so-called time-parallax phenomenon, and is a photogrammetric version of so-called constant-plane method, which is well-known in classical geodesy.

From the photogrammetric point of view the method presented hereunder consists in analytical, reciprocal comparison of photographs showing the successive state conditions of the surface which is subject to deformations.

The deformation value thus depends on the difference of image coordinates of the corresponding points on the photographs being compared and on the scale of a measuring point on the photograph.

This correlation can be expressed by the main formula:

$$P_{x,z} = r_{x,z} \cdot M_p \qquad /1/$$

where

$P_{x,z}$ is horizontal /x/ or vertical /z/ displacement of a measuring point,

$r_{x,z}$ is a difference of adequate image coordinates of the point,

M_p is a scale coefficient for the point.

For the discussed measurements the above formula may be expressed in the component form as follows:

$$P_x = (x'' - x') \cdot M_p = \left[(x''_{obs} + p_x) - x'_{obs} \right] \cdot M_p$$

$$/2/$$

$$P_z = (z'' - z') \cdot M_p = \left[(z''_{obs} + p_z) - z'_{obs} \right] \cdot M_p$$

where to

$$p_x = z d\varkappa - f \cdot \left(1 + \frac{x^2}{f^2}\right) d\varphi - \frac{xz}{f} \cdot d\omega + \frac{x}{f} df + \frac{x}{Y} dz + p$$

$$/3/$$

$$p_z = - x d\varkappa - \frac{xz}{f} d\varphi - f \cdot \left(1 + \frac{z^2}{f^2}\right) d\omega + \frac{z}{f} df + \frac{z}{Y} dz + q$$

The symbols used in the formulas /2/ and /3/ are as follows:

P_x horizontal displacement of point along the "x" axis,

P_z vertical displacement of point along the "z" axis,

x''_{obs}, z''_{obs} image coordinates observed on the "second" photograph taken after the deformation of the object,

x'_{obs}, z'_{obs} image coordinates observed on the "first" photograph taken before deformation,

p_x, p_z corrections to adequate coordinates on the "second" photograph recognized as necessary due to various data of inner and outer orientations of the compared photographs,

$d\varkappa$, $d\varphi$, $d\omega$ difference of angular elements of orientation of the photographs,

df difference of focal lenghts of the photographs,

dz component of stand displacement along the axis of the camera,

Y distance between the measuring point and the stand,

p,q observational corrections if necessary due to atmospheric refraction.

In the formula /3/ some other systematic errors are neglected, affecting the results of the photogrammetric plotting, e.g. distortion, two remaining components of a stand displacement /"dx" and "dy"/ and the instrumental errors of a stereocomparator or monocomparator. This omission is allowed owing to either the specific character of differential plotting resulting in the elimination of distortion or another way of observation on a monocomparator, described in author's report /3//this method eliminates the instrumental errors/, or last the relative character of deformation survey, which makes it possible to omit the "dx" and "dy" values.

It is evident from the above considerations that when aiming to attain deformation figures with a suitable accuracy, the necessity occurs to determine or eliminate the influence of seven remaining errors, $d\varkappa$, $d\varphi$, $d\omega$, df, dz, p, q, within the measurement and calculation procedure.

To keep this report within limits I'd like to refer to the above-mentioned publication /3/ wherein proved, simple and quick methods enabling to eliminate the influence of some errors / dz, p, q/ or to determine their value with an adequate accuracy are described.

In general, the method presented herein makes it possible to determine the displacements of points representing a large surface area along both the horizontal and vertical components.

2. Working program of studies on ship deformations.

A ship hull during erection has only one large surface accessible to be measured for a pretty long time, that is the upper deck surface.

For this reason and because of special interest of shipbuilders to this area of a ship the surface was examined with great care. The above-mentioned photogrammetric method was sketchily used. Average dimensions of the ships were: length-approx. 200 m, width-approx. 30 m, side height abt. 20 m and the upper deck surface measured 160 x 30 m.

Following, the working program is briefly presented. For each characteristic moment three photographs were taken from two photogrammetric stands suitably located on board /see fig.1 and 2/. It may be well to add that even one stand would give satisfactory results. The photographs were taken by means of two Zeiss Photheo 19/1318 cameras of focal length f = 195 mm the measuring points having been signalled on object beforehand.

For every measurement moment two or three negatives were then observed monocularly /by means of a monocular/ on a Zeiss Jena "stecometr" precision stereocomparator. The third negative was used only when essential discrepancies were occuring in the two preceding observations due to out-of-flatness of either photographic plate.

Correcting was made at the next stage and the corrections resulting from various data of the inner and the outer orientation of the photographs were calculated according to formula /3/. The photogrammetric plotting ended in calculation /acc. to formula 2/ of the ground deformation values which were presented in an ultimate /final/ form on special sketches and diagrams /see fig. 3/.

As mentioned above, detailed studies were carried out on the upper deck surface only. However, a number of extra measurements of vertical deformations was made by the precise levelling relating to other periodically accessible linear ship elements, e.g. the ship keel. The measurements were aimed at the determination of general deformation characteristics of the ship's total figure.

Parallel with those two procedures the thermovisional measurements of ship's sides and deck were carried out on the two vessels from among the five ones on a various scale /see fig. 4/. There were two purposes of these investigations: first, to determine the absolute thermal distribution on the ship's total figure cooled down in the night and unevenly insolated in the day, secondly, to examine the correlation between daily thermal changes within the ship's body and the corresponding deformations of the ship's hull.

The results of the discussed works enable to formulate conclusions regarding the ship's hull behaviour due to the launching and the daily temperature changes of the surrounding area. These conclusions are not, however, given herein for editorial reasons.

3. The evaluation of measuring accuracy.

Since the method applied in the investigations was new and regarding the so-far unknown character and magnitude of involved deformation, extensive check measurements were carried out with the use of photogrammetric and geodetic methods.

As a comparison effect of the results of these different methods, a final practically attained accuracy of the photogrammetric measurement was determined, expressed as the mean error of the determination of deformation. The accuracy figures were $\pm$ 1,0 $\div$ 1,5 mm.

Such an accuracy level for this large measuring area /160 x 30 m/ is to be recognized as very high. It is to empha size however, that in the discussed care, two factors conducive to this high accuracy appeared: first, the relative measurement character, and secondly, a very favourable geometry of the stand-object system, resulting in the optimum distribution of the points on the photograph.

4. Concluding remarks.

The photogrammetric method was chosen for its substantial benefits in respect of organization and technology. In particular, the method enabled to examine simultaneously the total ship's deck surface represented by a large number of points which described the object in a best possible manner.

In the measuring process some other benefits of the method were useful, too:

- the possibility of the determination of two deformation components during a single measuring and observational process,
- the possibility of the checking and, if necessary, correcting results to eliminate the effects of refraction and air vibration. The latter possibility is of great importance when examining the ship's deformation due to thermal changes,
- a very high plotting accuracy which is almost uniform within such a large object,
- convenient and time-sparing expenditure of field work,
- independent control of measurement, e.g. by the double execution of an examination cycle with the use of an additional measuring stand.

The measuring technology of the ship's hull deformation is closely described in the author's publication /3/. It is well to emphasize, that this technology now enables to examine the dynamical deformations of ship decks as well, for instance during the ship's exploitation or launching. In the latter case an accurate fixing of ship's position on a slipway is possible while taking the photographs of momentary ship's deformations.

References.

1. Laudyn I. Use of terrestrial single photograph measuring for the determination of deformations of structural elements, Issues of Warsaw Technical University, Geodesy,No15
2. Analytical photogrammetry, Warsaw, 1972,
3. Szczechowski B. Photogrammetric studies on object deformations with the use of a Constant-plane method. /Detailed description and measuring technology/, Gdańsk, 1978,
4. Szczechowski B. A new simple method of the determination of a ship's route and heels during launching, Gdańsk, 1979

Fig.1 Measuring photograph taken from the bow.

Fig. 2. Measuring photograph taken from the ship's quarter-deck.
○-measuring points

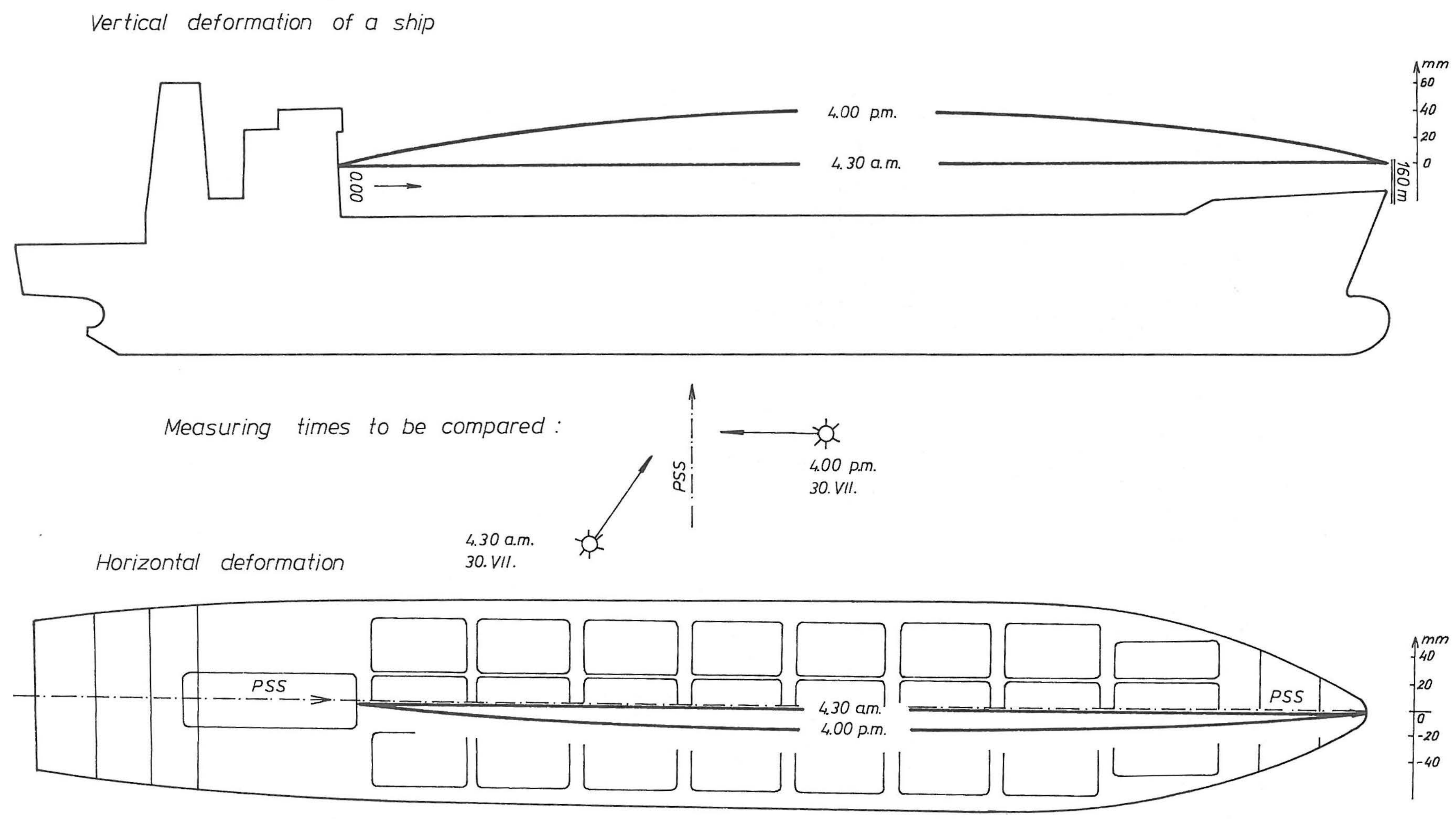
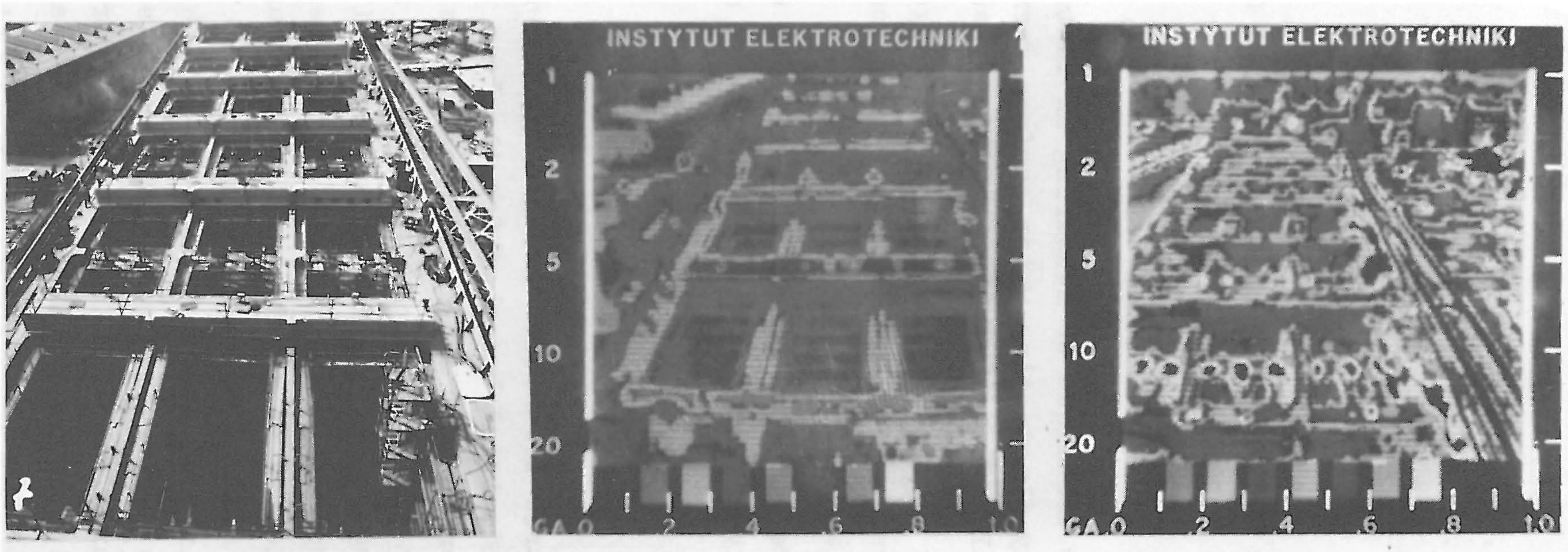


Fig. 3. Diagram of vertical and horizontal ship's hull deformations caused by insolation.



a

b

Fig. 4. Exemplary thermovisional photographs of the ship's deck, taken in the morning (a) and at noon (b).