PHOTOGRAMMETRIC CONTROL OF LARGE METALLWORK PRODUCTS

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The control of the quality of machine products requires the metrology analysis. Firstof all it conserns with the process of measuring, statistical processing of the measured quantitiens sach as actual dimensions, deviations of shape, positional deviations and deviations of size.

In accordance with the tolerances introduced in [1] the photogrammetric methods can be used for measuring dimensions over 2 m with tolerance 1 mm and more In these cases the usually devices and methods of machine metrology are cumbersôme and non efficient [2] . Using of laser interferometer or coordinate measuring machine is not operative because the measured part must be transported into the measuring laboratory. Inthese cases using the photogrammetric methods canbe very convenient.

The photogrammetric measurement of the plane objects.

The most frequent task of machine metrology is measuring of nominal dimension deviations or nominal position in plane. It is evident that for machine metrology in plane some of the one image photogrammetry methods can be used. On the bisis of analysis of the analytical photogrammetry methods the method of projective transformation in plane was chosen.

The projective transformation of two planes.

The projective transformation of two planes is expressed by known equations

$$x = \frac{a_1 x' + b_1 y' + c_1}{a_3 x' + b_3 y' + 1} \qquad y = \frac{a_2 x' + b_2 y' + c_2}{a_3 x' + b_3 y' + 1} \qquad (1)$$

where x, y are the coordinates of the plane object
x', y' the photograph coordinates
a_i, b_i, c_i coefficients of projective transformation

The properties of projective transformation

For investigating of the projective transformation properties a model simulation on microcomputer was employed. During the process of solution four mathematical models of photogrammetric camera were worked out

1. Model of ideal camera without lens distortion

2. Model of camera with lens distortion

3. Model of camera with variable principal distance and variable size of photograph

4. Model of camera with variable parameters of exterior orientation.

By means of the models mentioned above the influence of lens distortion and the interior and exterior orientation parameters on the changes of the plane object coordinates were investigated. The lay out of control and detail points created regular raster.

The results of mathematical model solution can be sumarized as follows :
The focal length directly determines the accuracy of photogrammetryc measurement there fore a scale must be selected inthe way which enables a maximal exploitation of the photograph size. The control and detail points have to lie in a plane. Lens distortion expresses the full error of plane coordinates, therefore it must be compensated. The parameters of exterior orientation cause the changes of scale therefore it is necessary to minimize the distance of photography and the numerical values of exterior orientation.

From the fundamental properties of projective transformation there results an important plane condition of object. In the opposite case the projective relation is deformed according to Fig. 1.

The photograph coordinates x', y' on Fig. 1 will show presence a their changes by the formulas

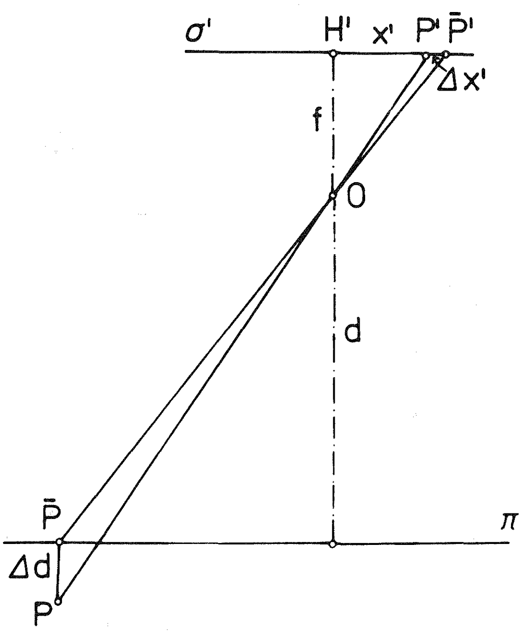

Fig.1. Deformation of projective relation

$$\Delta x' = \frac{\Delta d}{d} x' \; ; \qquad \Delta y' = \frac{\Delta d}{d} y' \qquad (2)$$

where d is distance of photography
Δd is deviations of a detail point towards plane

For distance of photography 3.3 m and $x' = y' = 60$ mm it will be maximum of deviations Δd from plane about 0.1 mm.

Besides the facts mentioned above the accuracy of photogrammetric measurement is influenced by other factors.

Other accuracy factors of photogrammetric measurement in plane

The accuracy resulting of photogrammetric measurement is influenced by

- primary accuracy of photograph coordinates
- accuracy of control points
- temperature influence

The accuracy of photograph coordinates is primary; This one and the scale determinate the accuracy of the plane coordinates and in this way the size of a machine part. By means of precise comparators we can measure the photograph coordinates with the accuracy within 1 - 2 um.

The accuracy of control points is derived from a requirement not to lower the accuracy of photograph coordinates. From this requirement there results the accuracy of control points within 0.05 - 0.1 mm. This very high accuracy of control points can be reached only by measurement on coordinate machine tool.

The temperature influence on measurement of large machine parts is considerable. For example the temperature change abont 1°C causes a deviation in diameter of 3 500 mm about 0.05 mm.

The photogrammetric measurement of large machine part

Projective transformation method with regard to mentioned factors of photogrammetric measurement accuracy was applied in control of partially worked out machine part with diameter about 3 500 mm /Fig. 2./

The photography was carried out by a terrestrial camera UMK 10/1318, with focal length f 99.67 from a distance about 3.3 m. The camera axis was approximately perpendicular to the machine part and passed approximately through its center. The scale reached the value about 1 : 33.

In the front of the machine part four pairs of control points and two levelling rods were placed. The coordinates of control points were measured by coordinate machine tool with accuracy characterized by standard error

$m_{x,y} = 0.02$ mm

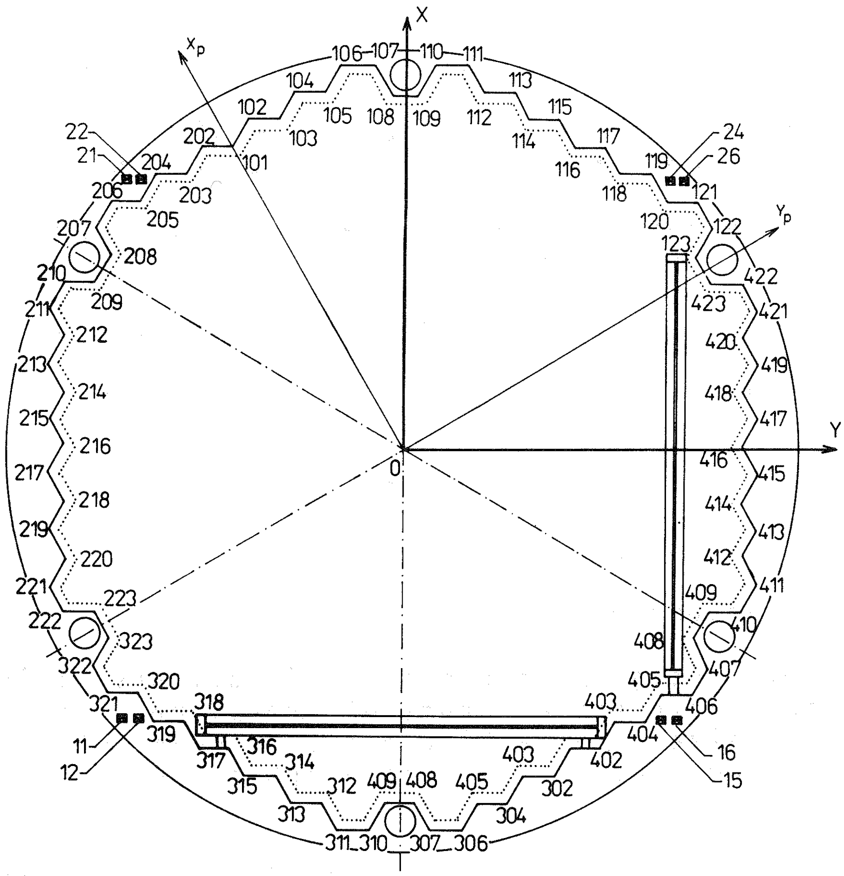

Fig.2. Control and detail points placed on machine part

The air temperature in the machine hall was about 20°C.

For the numerical control of photogrammetric measurement the invar levelling rods were placed in a plane of control points.

The detail points were represented by the worked corners of the machine part /Fig. 2/. They served for the determination of the machine part shape and were photogrammetrically measured directly.

The photograph coordinates of control points, control lenghts on levelling rods and detail points - work corners of the machine part were measured by precise comparator Komes 3030 - Zeiss Jena in several series. The achieved accuracy of comparator measurement is shown in the Table 1.

The accuracy of comparator measurement on control targeted points is characterized by standard errors

$$m_{x'} = 1.8\ \mu m \qquad m_{y'} = 2.3\ \mu m$$

The accuracy of comparator measurement on detail points /worked corners/ is characterized by these standard errors

$m_{x'} = 4.4\ \mu m$ $m_{y'} = 4.5\ \mu m$

For the photograph distances measured on levelling rods we achieved these standard errors

$m_{x'} = 3.1\ \mu m$ $m_{y'} = 4.2\ \mu m$

The purpose of photogrammetric measurement was the determination of the actual plane coordinates of the corners of the machine part /Fig.2./ with regard to its projected values. The projected coordinates of the corners were computed in coordinate system $X_p Y_p$. The photogrammetric comparator measurement was carried out in coordinate system XY being identical with coordinate system of machine tool. Transformation of coordinates between these two coordinate systems was realized by Helmert transformation equations.

The parameters of projective transformation, the coeficients of the equations /1/ were calculated as arithmetic mean from independent combinations of control points. The deviations after the mentioned projective transformation on control points achieved the values which are summarized in Table 2.

The residual errors after projective transformation can be expressed by standard error

$$m_{x,y} = 0.055 \text{ mm}$$

By a comparison of the control lenghts of levelling rods being placed in direction of coordinate system X and Y we obtained the following diferences :

Photograph Nr. 2 0.10, 0.02, 0.09, 0.24 mm
Photograph Nr. 3 0.17, 0.05, 0.22 mm

On the basis of the photogrammetric comparator measurement and data processing of the three photographs we acquired the statistical material for judgement of obtained photogrammetric measurement accuracy of the plane machine part. The accuracy was expressed as the standard errors of plane coordinates

$m_x = 0.21$ mm $m_y = 0.15$ mm

Conclusion

The example discussed in this paper indicates that the photogrammetric method of projective transformation fogether with photograph measurement on precise comparator is suitable forthe determination of shape large of machine products with accuracy within 0.1 - 0.2 mm.

Accuracy of comparator coordinates Table 1

Points	Photograph	m_x	m_y
	Nr.	[μm]	[μm]
Control	02	2.1	2.5
	03	1.6	2.1
Leveling rods	02	2.9	4.6
	03	3.4	3.8
Detail	02	4.3	4.5
	03	4.4	4.4

Deviations x, y on control points Table 2

Control point	Deviations on control points	
	x	y
	[mm]	[mm]
21	0.08	0.01
11	0.03	0.07
16	0.06	0.08
26	0.02	0.04
22	0.08	0.01
12	0.03	0.07
15	0.06	0.08
24	0.02	0.04

References

[1] ČSN 014420 Uniform System of Tolerances in Czechoslovakia

[2] Šíma, J.: Contemporary application terrestrial and close range photogrammetry, Supplement of GaKO, SNTL Prague, 1986