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PHOTOGRAMMETRIC MEASUREMENTS IN SHIP GYRATION STUDIES

ABSTRACT

Photogrammetric technology developed to check the driving parameters for designed ship gyration, using naval models, is presented in this paper. Photogrammetric records over the moving objects are taken by sequential and continuous exposures, with very large convergence and tilting angles. Image point coordinates of the model trajectory are measured in monocular vision, using a stereocomparator and they are processed analytically in a computer; besides the numerical results, a graphical plotting of the above-mentioned trajectory is obtained, using a proper programme. Some aspects related to control point markings and locations, their accuracy, the way to establish running tolerances necessary in the assisted-computer programmes, computation method and remarks regarding the aquired trajectory point accuracies required by the ship-building design and research activities are given, as well.

1.INTRODUCTION

The checking up driving parameters, using studies on the models of the designed ships, implies the necessity to record trajectories obtained during the tests, as well as their result processings, obviously, the photogrammetric methods being the most suitable to this purpose.

The driving tests referred to in this paper are carried out in a 40 m x 40 m covered basin; the height above the water level is about 11 m. The building is provided with artificial lightening systems, so that photographic recording is possible by continuous exposure.

In order to simplify the measuring and processing operations, as well as to reduce the general expenses, it has been adopted a method which requires the photographic recording from only two fixed stations placed on one of the basin sides, with the camera axes convergent and tilted at the angles: $\gamma = 88^{\circ}$ and $\omega = -43^{\circ}$, which gives a 100 per cent longitudinal overlap (Fig.1a -1b).The photograms were taken on photo-plates using two Zeiss Jena UMK 10/1318 cameras, with the focal lenghts of $c_s = 99.14$ mm and $c_d = 99.24$ mm; the distorsion errors correspond to the values indicated by the manufacturer for the infinity taking.

Due to the location conditions of the photographing stations and to the geometry of the resulted photograms, an analytical method has been adopted for the photograms point-by-point stereoplotting. The processing of the photogrammetric measurements requires a system of control points having three-dimensional coordinates and located in the area of the gyration basin, on all its sides (Fig.1a); control point marks have been provided with orientation devices and lightening systems, in order to achieve an optimum photo-recording and a correct identification during the photogram measurements.

The X,Y,Z -coordinates of the control points have been determined by topographic methods, having the following accuracy values:

$$m_X = m_Y = \pm 0.005 \text{ m} \quad \text{and} \quad m_Z = \pm 0.001 \text{ m}$$

2.TAKING AND MEASURING OF PHOTOGRAMS

The naval models which are the subject of the driving studies are equipped with a double-lightening device, made up of two electronic flashes with sincronic release placed on bow and poop, respectively; the interval between two releases can be set at 3 or 5 seconds.

Under these circumstances, the recording of the photograms can be performed in the two following variants:

a.- recording the control points by switching on their lightening systems and,

- recording, by continuous exposure, the succesive positions of the moving model by the intermittent release of the electronic flaches at the time-intervals mentioned above; all these recordings are performed without the general lightening system of the gyration basin;

b.- recording the control points, using the general lightening system of the gyration basin and,

- recording, by continuous exposure, the succesive positions of the moving model using its electronic flaches equipment, without the general lightening system.

The second solution has the advantage of a general image of the trajectory, but the reflections in the basin water cover some of the image points of the model track; so that, the first recording solution has been adopted, although the corresponding point identifications on the trajectory recorded on a pair of photograms are extremely difficult or even impossible during the image-coordinate measurements. In order to overcome this difficulty, the observations processing algorithm has the possibility to identify points corresponding to the two photograms of a pair automatically, their observation and measurement being performed entirely independent.

The image coordinate measurements are performed by monocular vision at a stereocomparator; the measurement accuracy of the image coordinates for one of the performed tests is shown in table no.1.

Table No.1

Category of observed points	Min.sq.er. (mm)	Max.sq.er. (mm)	Mean sq.er. (mm)
Control points	± 0.007	± 0.019	± 0.016
Trajectory points	± 0.006	± 0.023	± 0.013

The algorithm of the observations processing has possibilities to analyse data introduced in the computation, in order to detect and eliminate the possible erroneous observations, least these should affect the final results.

The elimination of the erroneous observations is performed by checking up some tolerances, experimentally established on basis of some tests performed with simulated data in different accuracy conditions, but considering the actual parameters of the photograms recording and control point location.

3.OBSERVATIONS PROCESSING

The driving tests of the naval models are carried out both in waveless conditions and in conditions of waves simulation; in both cases, it is necessary to know the three-dimensional position of the points on the model trajectory. So, an algorithm of analytical stereophotogrammetric evaluation of the recorded point observations has been adopted; this is provided with facilities for the automatic identification of the corresponding image points and elimination of the erroneous data, as well.

The relative orientation is performed using coplanarity equations of the two bundle of rays corresponding to the observed control points in a pair of photograms:

$$b_x \cdot (\, \bar{y}'_i \cdot \bar{z}''_i - \bar{y}''_i \cdot \bar{z}'_i \,) = 0$$

where: $\bar{y}'_i$, $\bar{z}'_i$ are the image-space coordinates of the control points, observed in the left photogram and transformed by rotation with the angles: $\varphi_1, \omega_1, \varkappa_1$;

$\bar{y}''_i$, $\bar{z}''_i$ are the image-space coordinates of the same points, corresponding to the right photogram and transformed by rotation with the angles: $\varphi_2, \omega_2, \varkappa_2$;

b_x is the arbitrary component of the model basis.

In the computation process, we consider $\omega_1 = 0$, $b_y = b_z = 0$;

the value of the b_x component is 400 mm (about 1/100 of the actual value of the photograms taking basis).

The computation process of the relative orientation is iterative, its cease being determined by the simultaneous achieving of the two following conditions:

- the stability of the solution indicated by a variation of the r.m.s. vertical parallax in the control points lower than 0.0005 mm and,
- the obtaining in each control point of a residual vertical parallax lower than a tolerance which is pre-established by means of the graph in Fig.2.

The combination of the two above-mentioned criteria leads both to the achieving an optimum solution of the relative orientation elements and to the possible elimination of the erroneous observations in the image coordinates, which might bear negatively upon the computed coordinates of the stereomodel points.

As it was mentioned above, one of the difficult problems arising in the point-by-point photograms stereplotting of a moving naval model taken by continuous exposure of the entire trajectory on the same images is the correct identification of the corresponding points in the both pair recordings. To overcome this difficulty, the computation algorithm of the stereomodel coordinates has the possibility to identify the correspondent points of the trajectory automatically, by a sorting process consecutive to the process of determination of the relative orientation elements; The sorting process is carried out dynamically by checking up the minimum condition on vertical parallaxes computed for all the points of ship trajectory. A test shall be simultaneously performed regarding the tolerance imposed for the process of the relative orientation, which gives the possibility to eliminate some erroneous data in the image point coordinates.

The absolte orientation is, also, performed in an iterative computation process, based on transformation relations of the stereomodel coordinates:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_i = s . R_{(\varphi,\omega,\varkappa)} \cdot \begin{bmatrix} x \\ y \\ z \end{bmatrix}_i + \begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix}$$

where:	X_i, Y_i, Z_i	are the coordinates of an observed point in the object-space system;
	x_i, y_i, z_i	are the stereomodel coordinates of the same point;
	s	is the scale factor of the stereomodel;
	$R_{(\varphi,\omega,\varkappa)}$	is the rotation matrix of the angles $\varphi, \omega, \varkappa$
	X_o, Y_o, Z_o	are the displacements corresponding to the coordinate axes.

The ending of the absolute orientation computation process is determined by the accomplishment of some stability and accuracy conditions similar to those of the relative orientation.

The whole computation process described above has been programmed in Fortran language; the final output data consist of the list of the object-space three-dimensional coordinates of the points defining the recorded ship model trajectory. With an auxiliary programme, an automatic graphical representation of the trajectory points can be obtained using a plotter, at a proper scale.

4.EXPERIMENTAL RESULTS AND CONCLUSIONS

Observation processing of one of the pair of photograms taken under the above-mentioned conditions (Fig.3) gave the results shown, as an example, in table no.2.

The graphical representation of the computed coordinates of the observed points renders the trajectory of the naval model (Fig.4) making possible the performing the required studies regarding the driving parameters. The analyses of the final data resulted in a 0.005 m accuracy for the control distance between the "bow" and "poop" points. The experimental studies give the possibility to draw the following conclusions:

- the application of some automatic identification methods of the correspondent points defining the trajectory recorded on the two photograms of a pair simplifies the image coordinates measurement process and increases the certainty degree of the final results;
- the applied method is economical from point of view both of the required photogrammetric equipment and photosensitive materials, and amount of computation necessary for observation processings
- the photogrammetric determination of the trajectory of naval models which are a subject of driving tests in gyration meets the accuracy requirements imposed by the designers and researchers in the field of the naval constructions.

Table no. 2

Computation step	Number of points	Number of iterations	Res.v.par. max. (mm)	Res.v.par. m.s. (mm)	Res.err. of ob.-coord max. X-Y (mm)	Res.err. of ob.-coord max. Z (mm)	Res.err. of ob.-coord m.s. X-Y (mm)	Res.err. of ob.-coord m.s. Z (mm)
Rel.orient.	14	9*)	0.052	0.015	-	-	-	-
Stereomodel	38	-	0.086	0.042	-	-	-	-
Abs.orient.	12	5	-	-	26	17	16	11

*) including the detection and elimination of two erroneous points of relative orientation

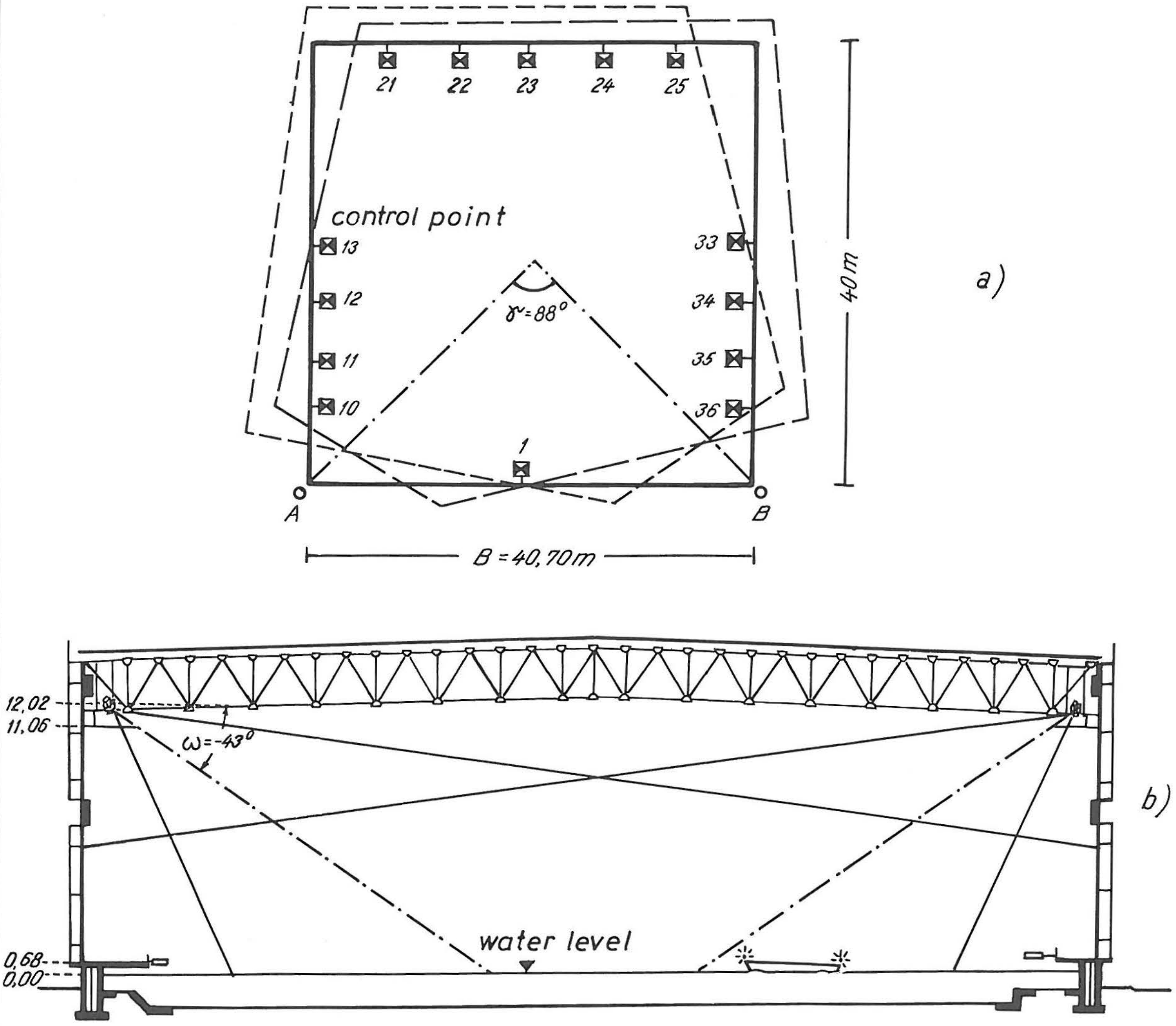

Fig. 1 - Location of photographing stations and control points

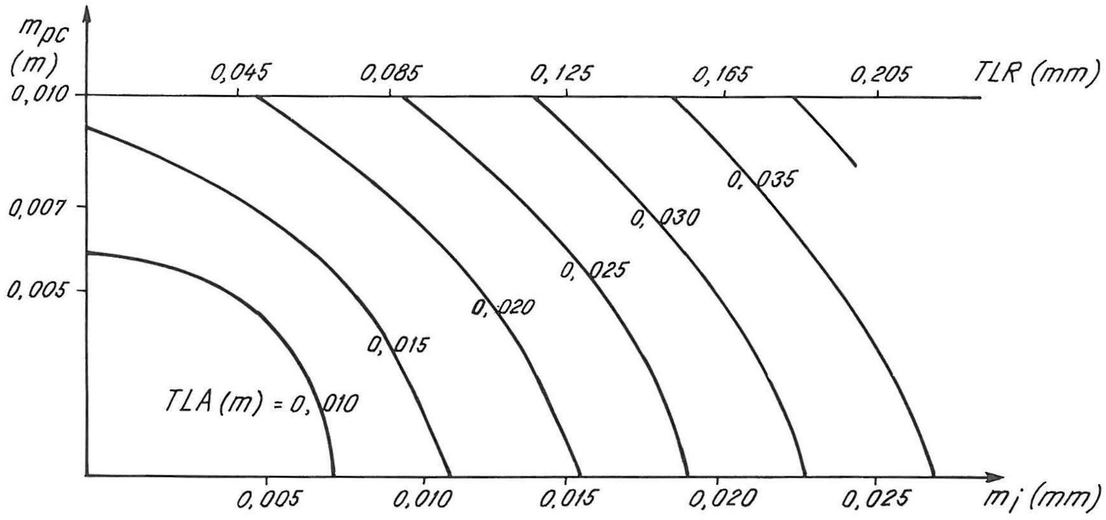

Fig. 2 - Diagram of computation tolerances for relative orientation (TLR) and absolute orientation (TLA)

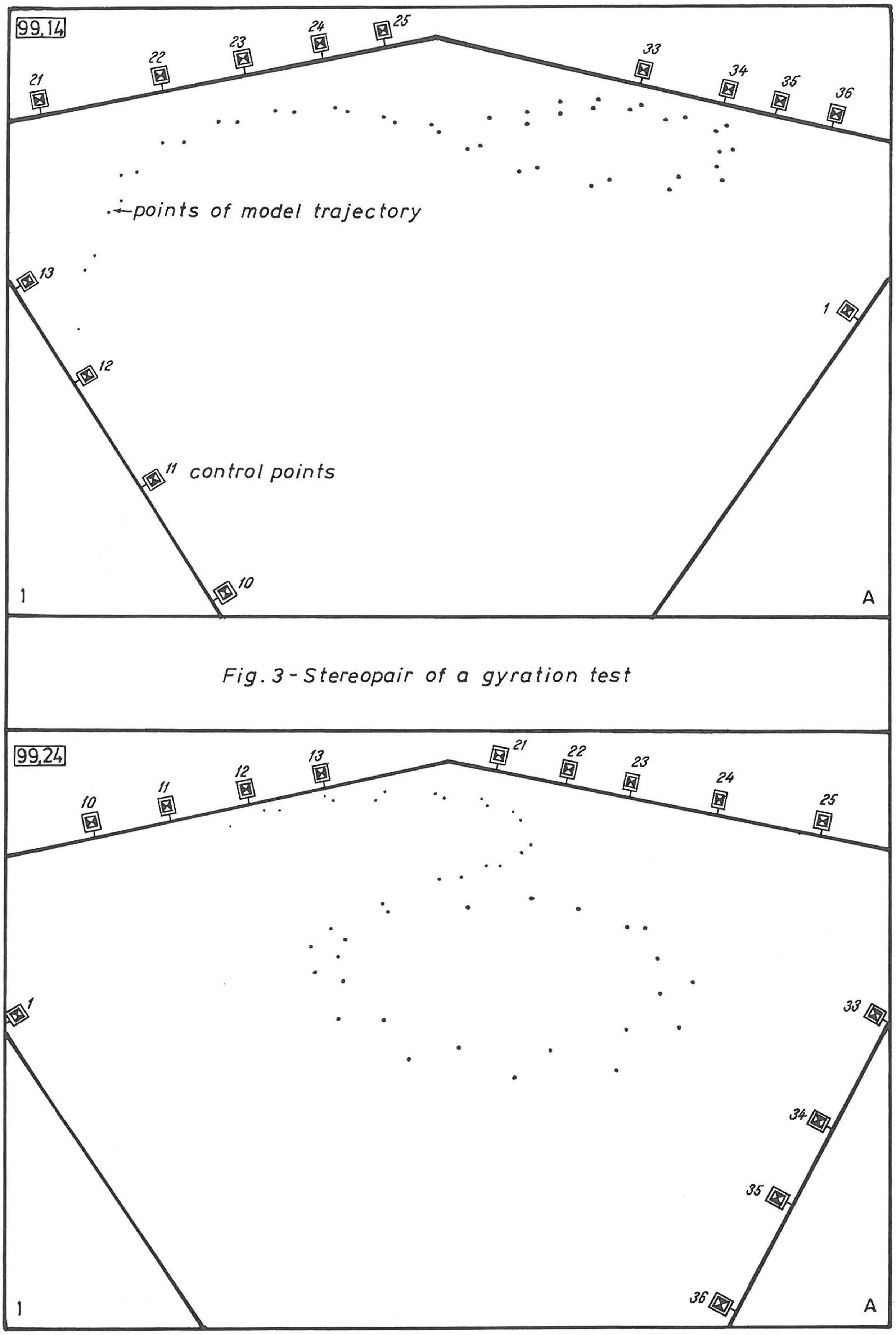

Fig. 3 - Stereopair of a gyration test

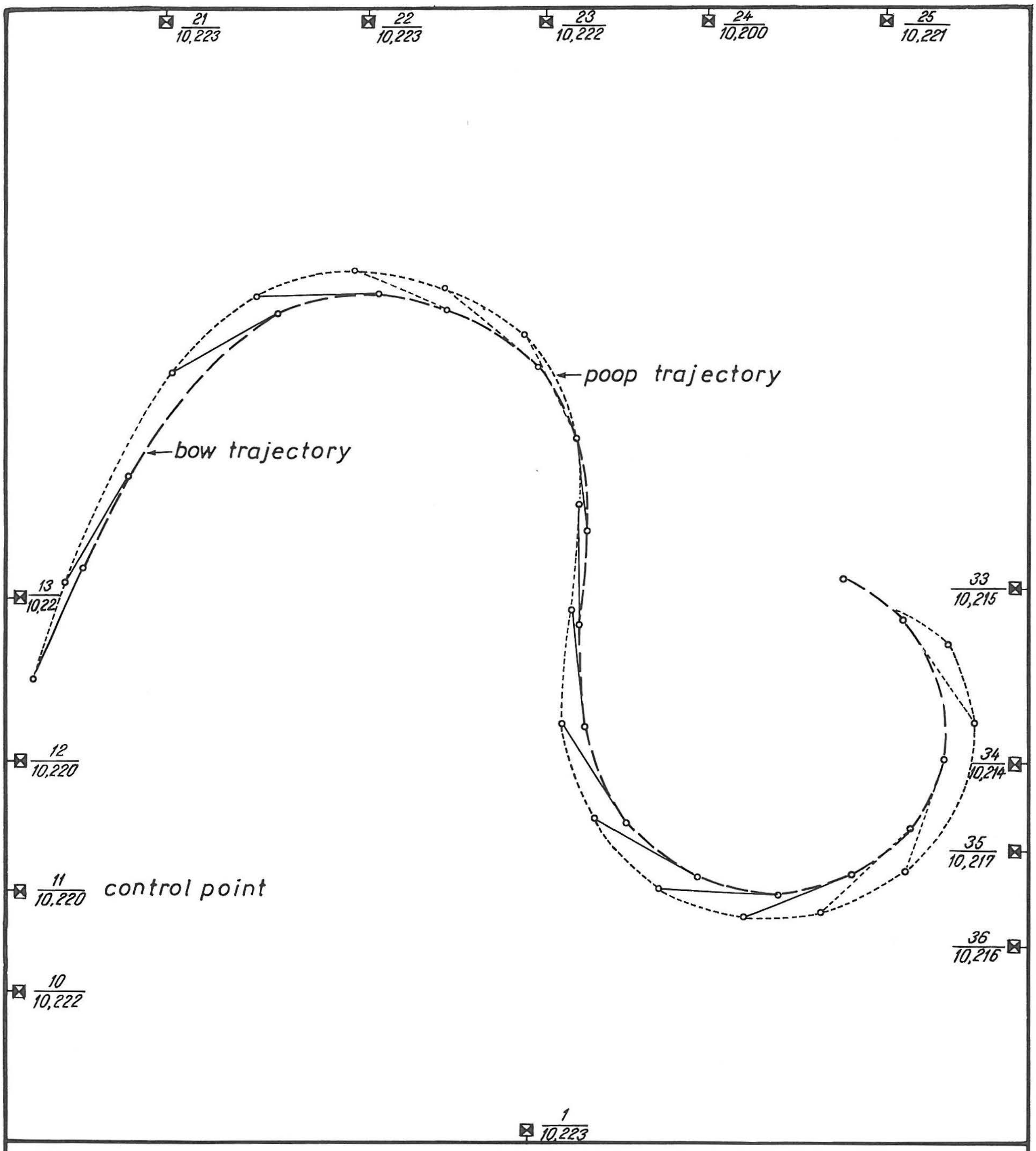

Fig. 4 - Plotted trajectory of the gyration test in fig.3