APPLICATION OF GPS RTK TECHNIQUE TO SHIP HULL TRAJECTORY DETERMINATION DURING LAUNCHING

Zofia Rzepecka, Alojzy Wasilewski

Institute of Geodesy,
University of Warmia and Mazury in Olsztyn
Oczapowski Str. 1, 10-957 OLSZTYN
e-mail: *alekw@uwm.edu.pl*

Abstract

The Institute of Geodesy began a co-operation with the Shipyard of Gdansk in the field of studies of the ship hull deformations during the process of launching. Some introductory remarks concerning the process of ship launching open the paper. In this context it is explained what will be the subject of our studies. Up to now, one GPS experiment, aiming at checking the possibility of application of GPS technique to these purposes has been carried out. Description of the encountered problems together with the near-future plans in this field is given in the paper.

1. Introduction

In a typical course of along ship launch, the following stages can be distinguished:
- Stage I - from start of the movement to the moment of reaching the water,
- Stage II - from reaching the water to the moment of the stern rotation,
- Stage III - from start of the rotation to the moment when the support of the ship bow goes down from the slipway (ramp) to the water,
- Stage IV - from the above moment to the moment when the ship stops.

The most dangerous for the ship is Stage III. Large bending stress at the moment of the rotation causes large compressive stress on the deck, and tensive stress in the ship bottom. Our general goal is to detect the deformations using GPS technique. For this purpose we need to determine exact positions (on 1 cm level of accuracy or better) of some GPS satellite antennas arranged properly on the ship, at successive individual epochs of time.
The practical GPS experiments were performed during real launching of a ship at the Gdansk Shipyard. In next chapters of the paper we give short description of both the experiments, obtained results, accuracy analyses, further requirements, plans for the nearest future in this field of studies.

2. Ship launching – basic information

As it has already been mentioned, there are four stages of along ship launching. *Stage I* occurs only in the case of open slipway - the ship before the process stands above the level of water and it must go a proper way before reaching the water. The ship standing on the slipway is subject to the force (Fig. 1):

$$K = Ds\ (\ tg\ \beta\ - f_s\ )$$

where: f_s – coefficient of static friction. It is about twice as much as the dynamic friction coefficient: $f_s = 2f_d$.

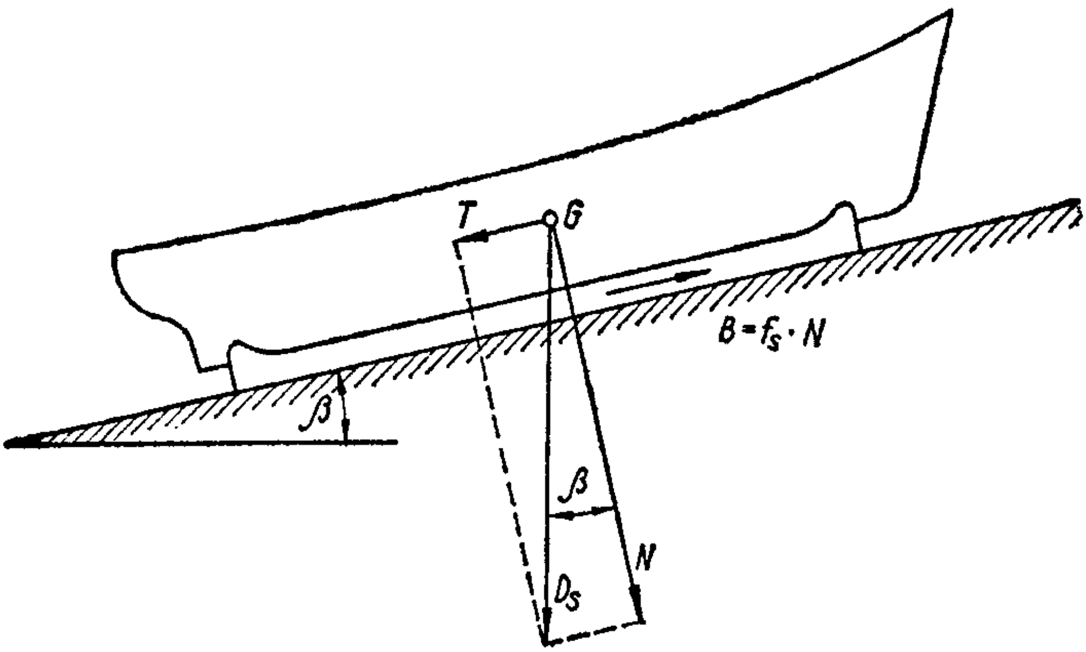

Fig. 1. Forces acting on a ship standing on the slipway

Stage II of the launching begins with the moment of reaching the water. During this stage the hydrostatic lift increases. Pressure of the ship onto the slipway decreases as much as the hydrostatic uplift of the immersed part of the ship hull increases. During *stage III*, in the effect of increasing hydrostatic lift pressure, the angle of the lengthwise slope decreases, while the front part of the ship still rests on the slipway tracks, exerting non-decreasing pressure on them. In *stage IV* the down pressure, which at the beginning of the III stage reaches its maximum value, begins to decrease as the uplift hydrostatic pressure increases. The down pressure disappears completely at the moment when the whole ship is on the water. At last, the kinetic energy of the ship is lowered to stop the ship at a determined distance from the slipway. The most dangerous for the ship is *stage III*. Large bending stress in the moment of the rotation causes large compressive stress on the deck, and tensive stress in the ship bottom. Under these kind of forces the ship hull deforms bending down (dashed line in Fig. 2a), next, after further slipping along the slipway, an opposite bending moment of the force, which causes compressive stresses in upper parts of the ship, and tensive stresses in its low parts. In effect, the ship hull deforms bending in up-wise direction (Fig. 2a, 2b).

Up to now the deformations of the ship hull during the process of launching were measured with application of various techniques as photogrammetric, laser, optical etc. The deformations of the hull are fast-changeable processes and observations and recording requires proper methods and equipment. It seems that the GPS technique will meet the conditions of this measuring task. At the Institute of Geodesy, University of Warmia and Mazury in Olsztyn, the task of application of the GPS technique to study of deformations of the ship hull during its launching has been undertaken.

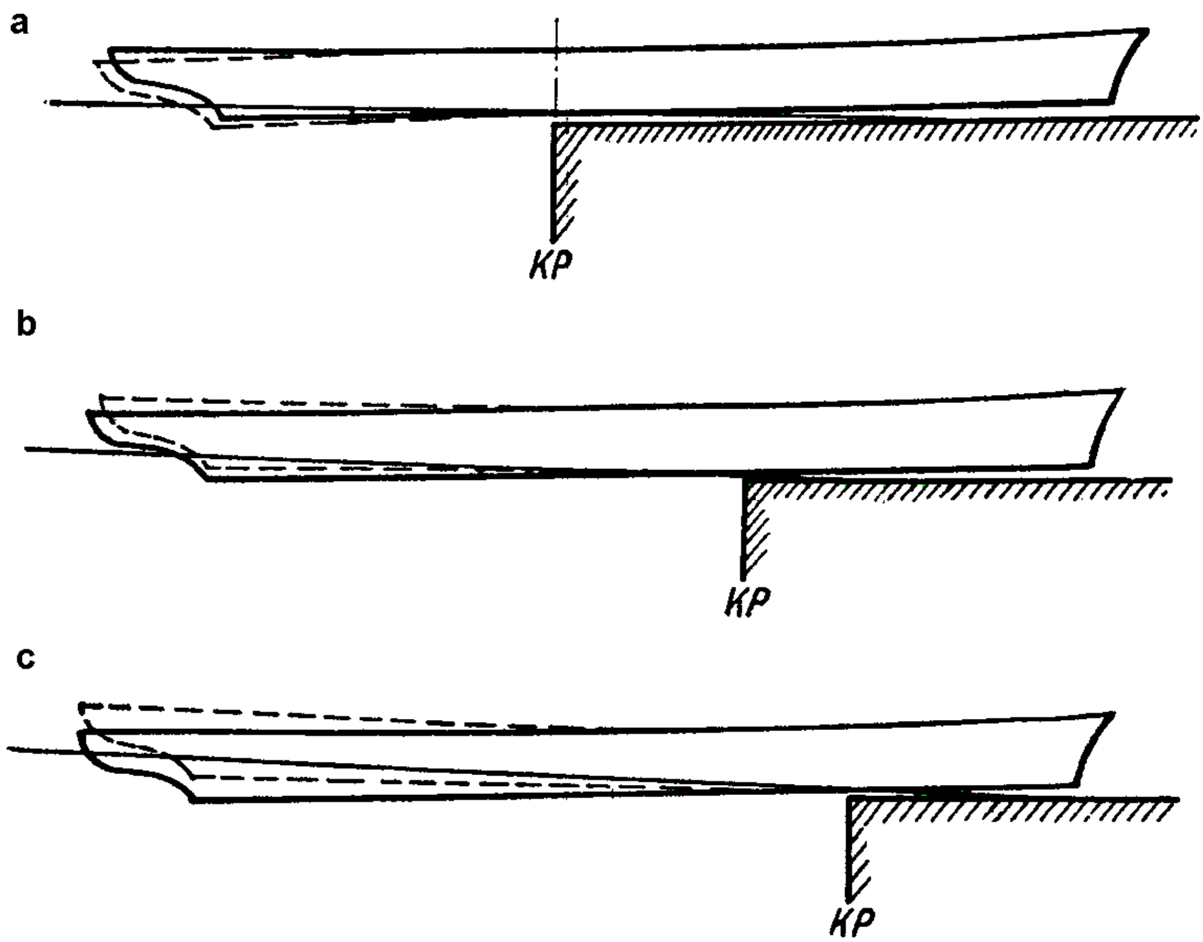

Fig. 2. Ship hull deformations during launching

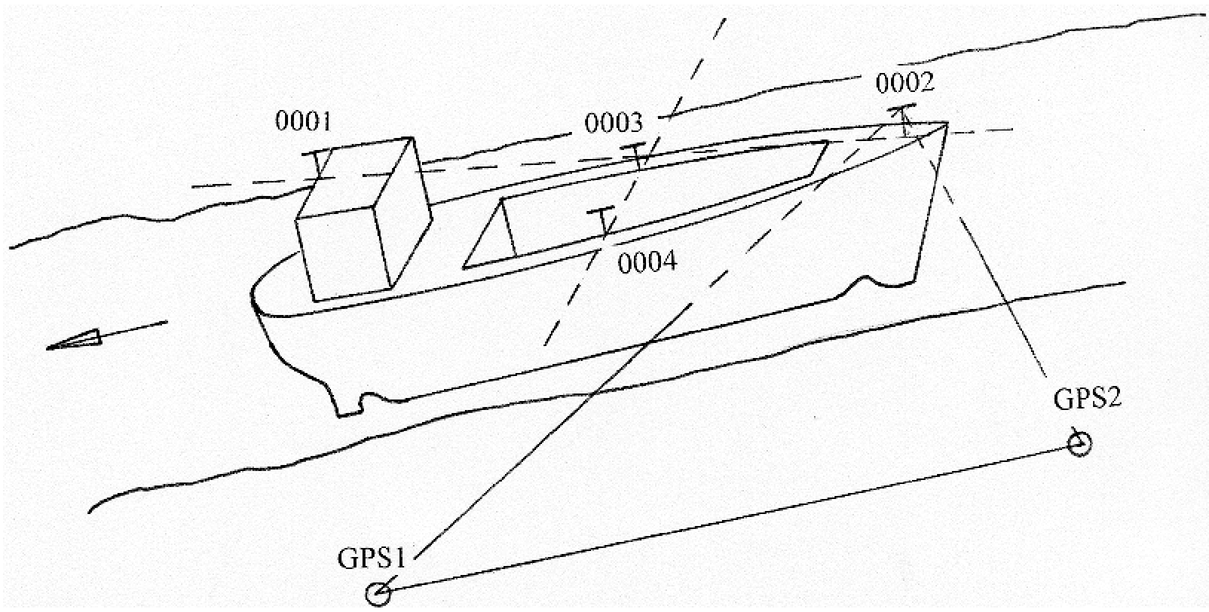

Fig. 3. Arrangement of the GPS experiment

3. Description of the experiment performed on a ship

Practical experiment was carried out in Gdansk Shipyard, during end launching of a ship hull, on an open slipway. The places for forced centering of the satellite antennas were prepared before the measurement. The arrangement of the experiment is shown in Fig. 3. Two reference GPS receivers were located on-shore and 4 were attached to the hull. Z-Surveyor and Z-12 Ashtech receivers were used. Recording interval was set to 1 sec. Recorded data were post-processed using PNAV and AOSS programs. Because of the forces, tensile or compressive, acting on the hull during the launching, the control points located on its stern and bow as well as on its sides, will be displaced in respect to each other. The main principle of determination of lengthwise deformation of the hull is given in Fig. 4. The method of determination of the value of U can be shortly summarised as follows:

- vertical plane Π passes through the points 0001 and 0002
- P is the point of intersection of the straight line 0003-0004 with Π, its co-ordinates can be found
- the interval U_0-U_1 constitutes the distance between the point P and the straight line 0001-0002 on Π
- then the displacement of the point P_0 in respect to the points 0001, 0002 can be determined ($U=U_1 - U_0$).

The most convenient way to perform the computation is to transform the co-ordinates of GPS points into a local system of co-ordinates, connected with the reference points GPS1 and GPS2. Such a system can be regarded as 3-dimensional and vertical directions as being parallel.

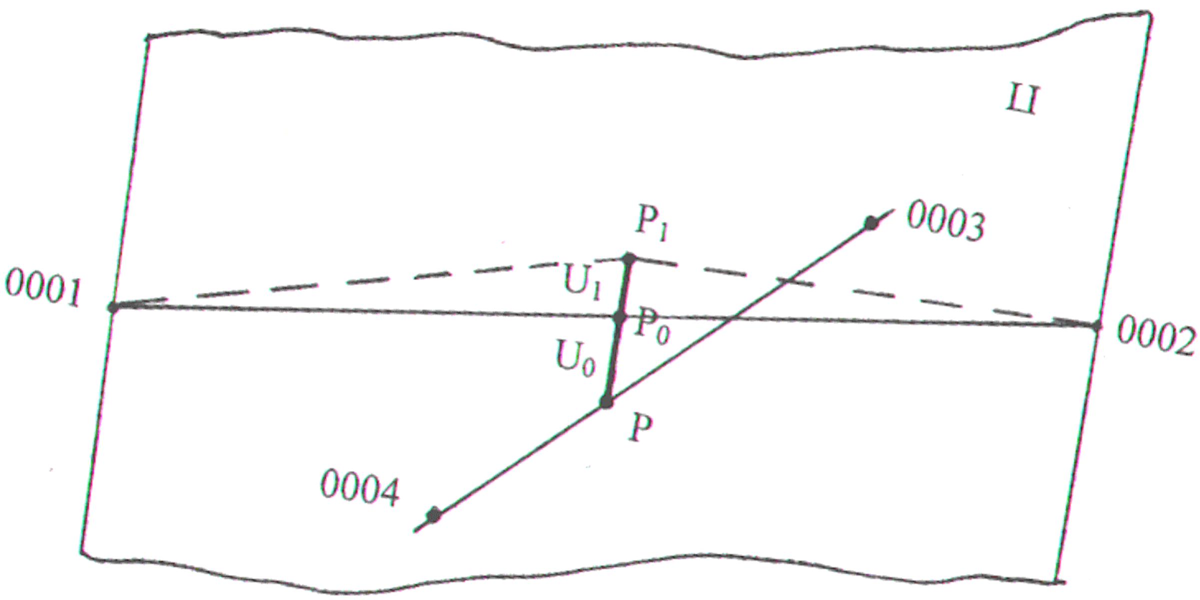

Fig. 4. Principle of determination of the hull deformation determination

Accuracy of GPS stations determination should be of the order of 1 cm, since the expected deformations of the ship hull (its length was about 100 m) can reach 5 cm. Unfortunately elaboration of the recorded data proved that the obtained accuracy was worse than that.

3.1. Elaboration of results and accuracy analysis

Recorded GPS raw data were post-processed using two available computer programmes: Precise NAVigation – PNAV (Ashtech, 1994) and Ashtech Office Suite for Survey (Ashtech, 1977). Both of them offer possibility of determining positions of rover antenna for each epoch of observation. The algorithm used in PNAV is given in (Xinhua Qin, 1992). Generally speaking, it takes advantage of Kalman filtering technique, using code and phase observations on both L1 and L2 frequencies. Two observation sessions were carried out: static and kinematic. In the case of using PNAV for kinematic positioning, the static session was elaborated with GPS Post-Processing System GPPS (Ashtech, 1990).

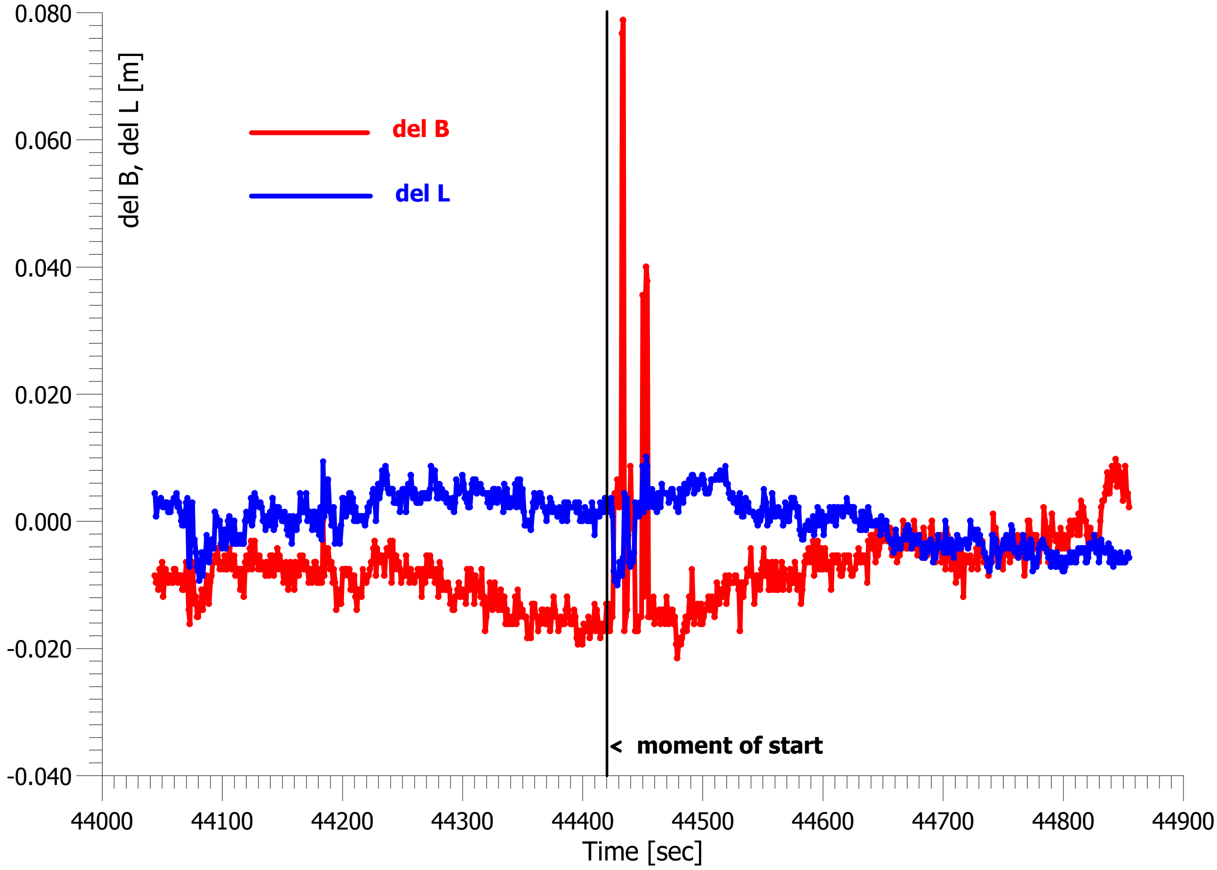

Fig. 5. Differences between B and L of 0001 obtained from GPS1 and GPS2 (PNAV)

It can be seen from the plot that the test failed. For determined heights the differences between the values obtained from the both reference points reached 12 cm. Results obtained for other points located on the hull were similar. The data were computed using PNAV software, fixing the co-ordinates of the reference stations as obtained from static elaboration using GGPS v. 5.2 system. Chosen options in PNAV were as follows*: navigation/ship/use all observables/medium multipath.* The discrepancies reach 10 –12 cm, this is too bad for our purposes. For AOSS results only the test of distances was performed. The changes were even bigger then that for PNAV solutions, reaching 20 cm. More detailed analyses are given in (Wasilewski et al., 2000 and Rzepecka, 2000).

After obtaining so inaccurate results we approached looking through recorded raw data more carefully. It proved that there were a lot of very big gaps in observations. They were probably caused by cranes and scaffolds located in vicinity of the hull. It is difficult to provide full visibility for the antennas mounted on the hull, but perhaps it would be possible using special extension arms of proper lengths. The analyses also proved that the determinations obtained from the GPS1 reference are much better than those computed from the GPS2. It was proved in the cited works, that the bad quality of the data was caused by occurring cycle slips. Therefore for further elaboration we took only the data obtained from GPS1 reference point. All the determinations from GPS1 during the period of interest have the RMS's values of the order of 2 cm. Having to our disposal only one reference point, accuracy of the data could be further checked using the distances computed on the basis of obtained co-ordinates of the on-ship points. If the ship hull would bend to about 5 cm (as it is foreseen) the changes in distances should not be greater then some millimeters. But it is not the case with our results. Example of the computed distances between the points 0001-0002 is given in Fig. 6. The greatest deviations can be seen at the moment of deepest submersion of the point 0001.

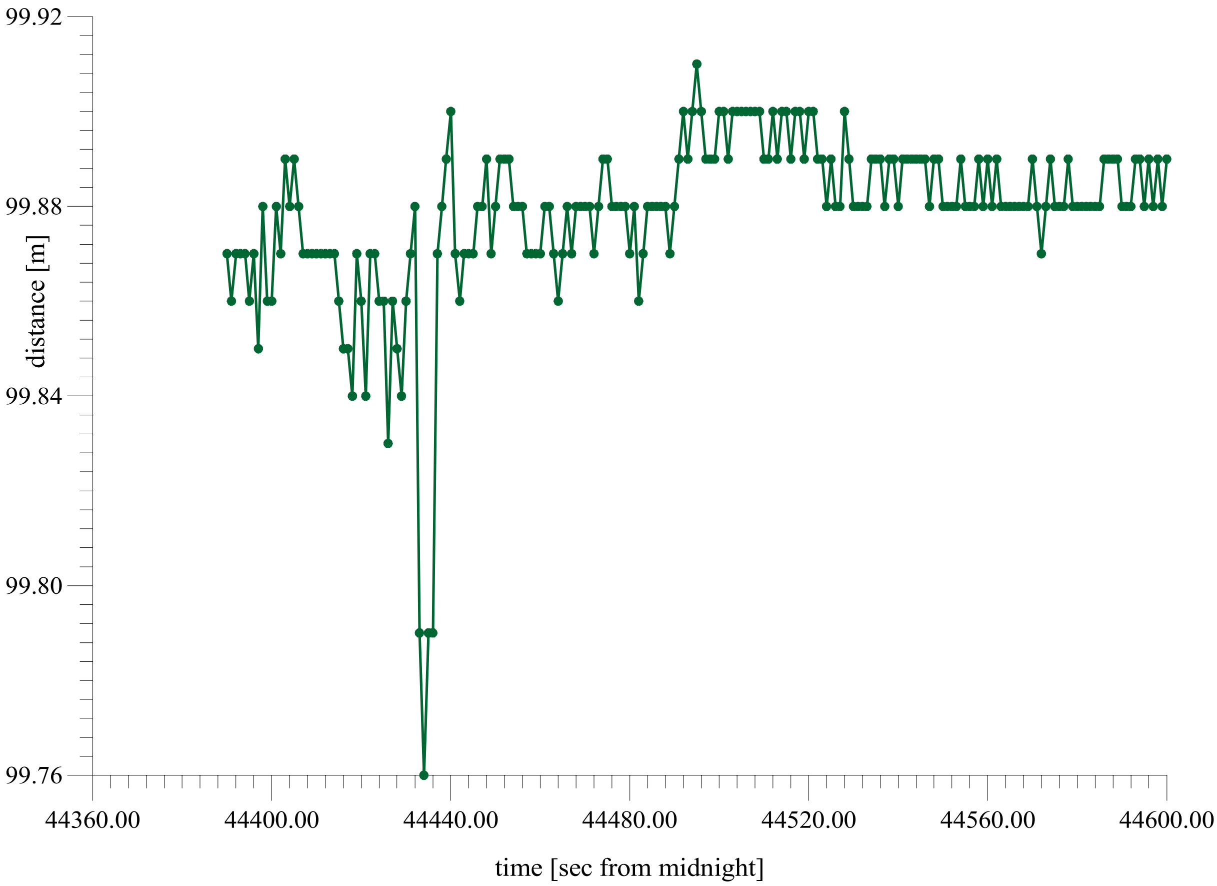

Fig. 6. Changes in distances between points 0001 and 0002 during launching.

It is rather difficult to interpret the results, since there is no independent quality inspection. Thus further experiments are needed, with almost two reference points, with equally good results. It seems that it could be accomplished under good visibility condition – having data without cycle-slips.

4. Trajectory determination

The accuracy of the results can be estimated to about 10 cm. It is not possible to perform analysis of the ship hull deformations during launching but it is enough for trajectory determination. It is possible to monitor the behaviour of the hull treated as a rigid body. As an example, there are 3D trajectories given in figures 7 and 8, of the point located at the stern and at the bow respectively. The computed ellipsoidal heights of these same points, plotted versus time, are given in figures 9 and 10. It can be seen that it is possible to determine how the hull swings, how deeply it submerges into the water, its velocity, etc. during the launching.

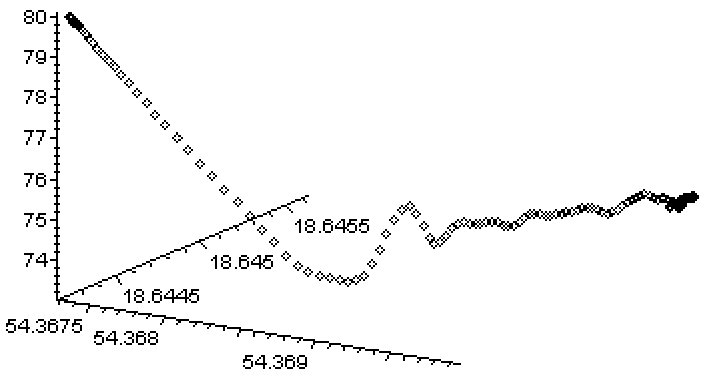

Fig. 7. 3D trajectory of the GPS point located at the stern

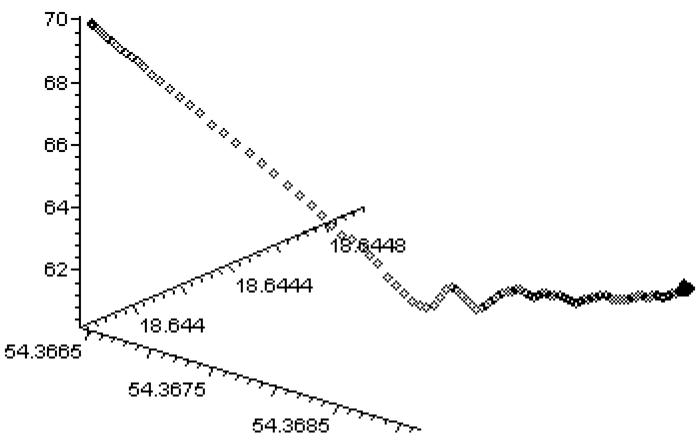

Fig. 8. 3D trajectory of the GPS point located at the bow

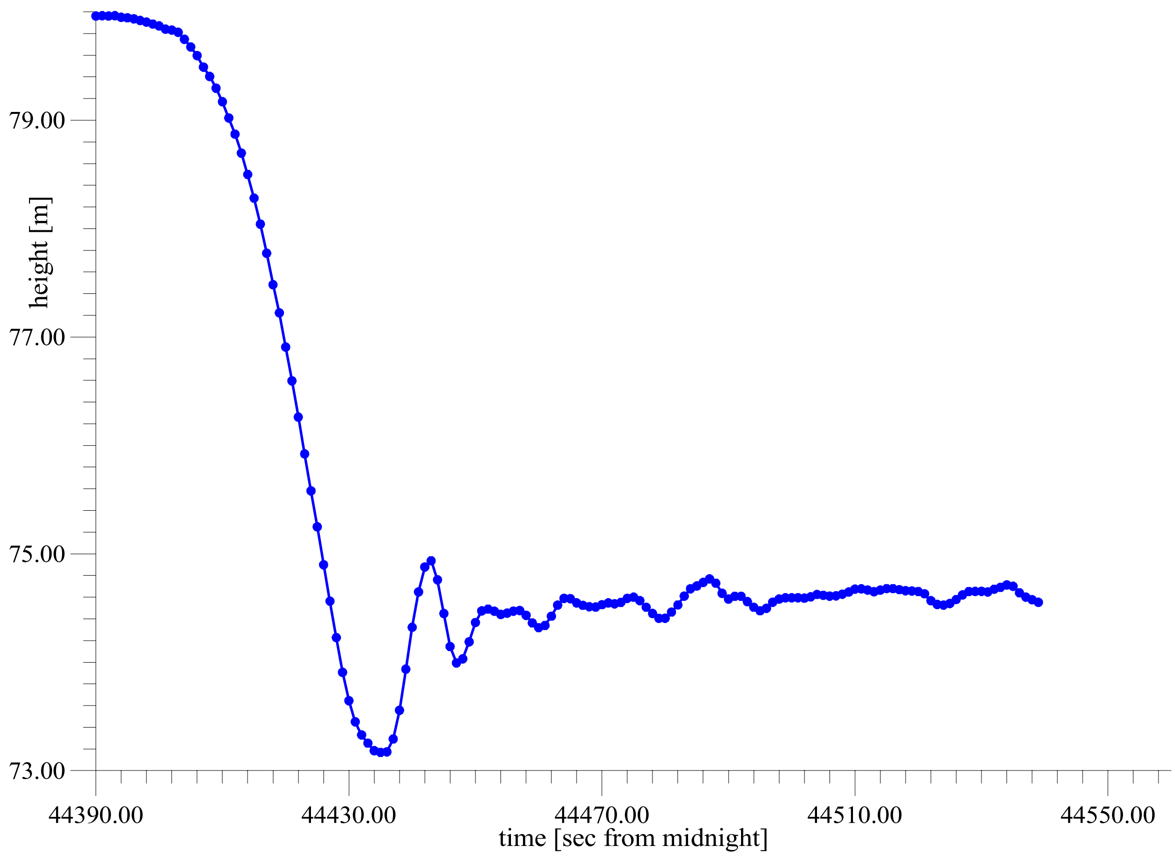

Fig. 9. Computed ellipsoidal heights of the GPS point locates at the stern

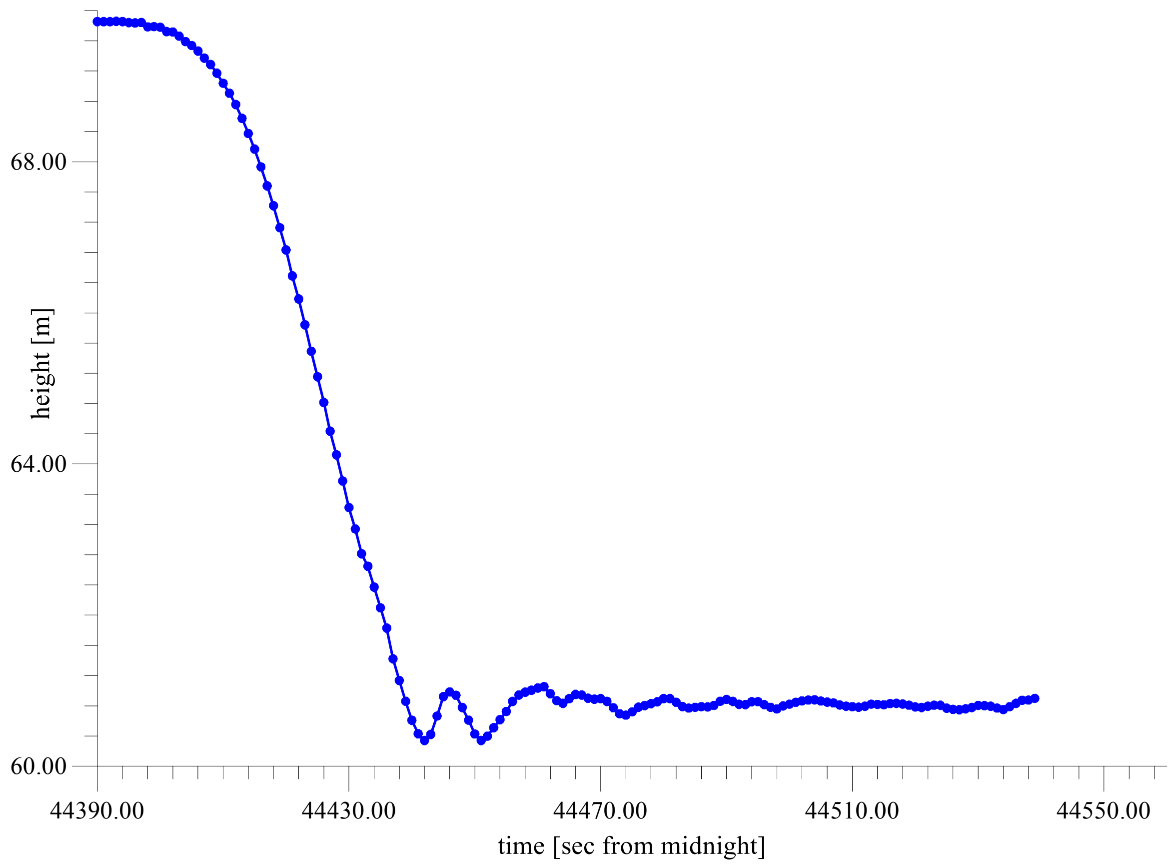

Fig. 10. Computed ellipsoidal heights of the GPS point locates at the stern

5. Conclusions

1. The estimated accuracy obtained with application of available hardware and software for kinematic positioning is of the order of 10 cm under difficult observation conditions (obstructions and resulting gaps in raw data files).
2. Such accuracy does not meet requirements of launched ship hull deformation studies. The required accuracy should be of the order of 1 cm.
3. Having positions of points located on a ship hull with 10 cm accuracy enables determination of its trajectory, swinging, depth etc.
4. Our plans in the field of checking possibilities of application of the GPS technique to studies of ship hull deformations during launching are as follows:
   a) to check out what accuracy will be provided by different programmes, released by another incorporations (input through Rinex format)
   b) to create own software dedicated for these purposes.

References

1. Ashtech Inc. (1990). „ Ashtech XII GPPS" (*Manual*), Sunnyvale, USA.
2. Ashtech Inc. (1994). „Precise Differential GPS Navigation – PNAV". *Software User's Manual*. Sunnyvale, Kalifornia, USA.
3. Ashtech Inc. (1997). "Ashtech Office Suite for survey". *User's Manual*. Copyright by TerraSat GmbH, Germany and Ashtech Inc., Sunnyvale, CA, USA.
4. Doerffer J. (1967). "Technology of Ship Hull Building". *Maritime Publishers in Gdynia* (in Polish)
5. Rzepecka Z. (2000). "Accuracy of GPS Epoch-to-Epoch Positioning of a Moving Object". *Technical Sciences*. Warmia and Mazury University in Olsztyn Press (Publishers UWM)

6. Wasilewski A., Rzepecka Z., Kapcia J. (2000). “Preliminary Studies of Precise Positioning of a Moving Object Using GPS RTK”. *Reports of Geodesy*. Warsaw, Poland
7. Xinhua Qin, Gourevitch S., Kuhl M. (1992). „Very Precise Differential GPS - Development Status and Test Results”. *Proceedings of ION GPS-92*, Albuquerque, New Mexico.