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DEFINE THE PARAMETERS OF HYDROGRAPHIC SURVEYING IN LOW DANUBE BRANCH

Target setting. In existing surveying systems and if certain prerequisites are met (for example, transducers are approximately vertical beneath the positioning, no roll angle sensor, etc.), simplified methods can be used, but the precision claims and verification must be guaranteed for obtain the dynamic characteristic of see bottom.

Analysis of last publications. Local parameters of surveying is determinate the spatial reference of sensors in the ship's coordinate system and deep measurement system. The testing is set up and performed so that gross errors can be recognized directly on site or can be reliably eliminated during the evaluation [1 - 7].

Purpose. These notice describe the testing and and making of requirement some equipment in the measurement system if specifically requested by the hydrographic surveying with dinamic see bottom tasks. The testing proceedure is a sequential process, so that the sequence of test steps must be adhered to in any case. If only a single sensor is tested, it must be ensured that the other sensors are working properly.

Height-based Testing of Ships positional with the different conditions.

In 2009 year during the Summer Time, State Hydrographic Service held to pursue research of dynamic evaluation of river bottom in Low Danube river branch. For that reason, the first step they have calculated and made the testing some parameters of Hydrographic surveying.

On-board Testing: The C probe have been tested and compared to a calibrated C probe by taking a common profile simultaneously at the same location. Compare the measured deviations with the permissible deviations as Fig. 1. The water sound velocity is calculated using the Del Grosso (1974) formula using the measurement of temperature-salt content and air pressure, and is compared to the value measured by the probe. Check to see whether the deviations are permissible.

Data age is understood to mean the deviation of internal sensor clocks to a reference clock.

Testing of correct temporal assignment of the positioning system and the depth measurement (Fig. 2):

passed over a prominent object at a high rate of speed and store the measurement (speed from GPS);

passed over the same object in the same direction at half the speed and store the measurement (speed from GPS);

measured the apparent position shift of the object between the two measurement runs;

calculated the data age t from the speed difference (v_2 - v_1) and the position shift;

calculated the uncertainty of the calculated data age t from the formula given below.

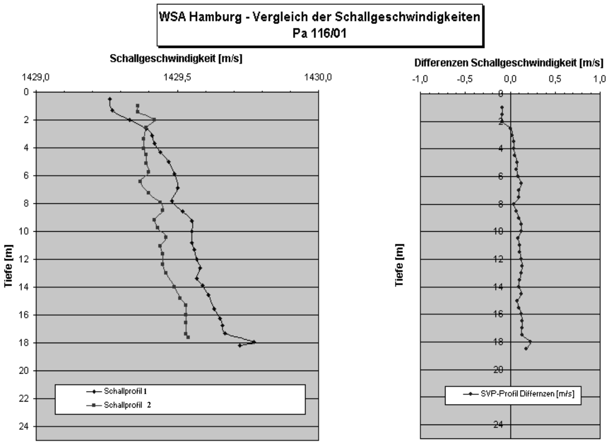

Fig. 1. Apparent comparison and difference calculation: comparison of sound velocities sound [sonic] velocity; differneces; sound profile

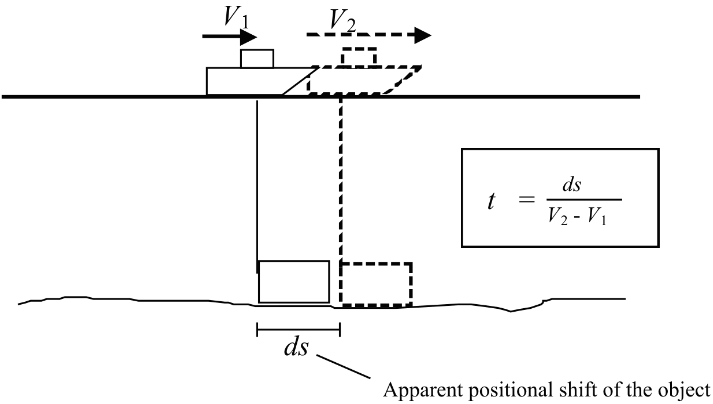

Fig. 2. Temporal assignment of the positioning system

Checked the magnitude of the uncertainty compared to the calculated value. The data age have been determined at least two times.

As an alternative to the procedure described above, computerized processes have been used when they enable a statistically confident assessment and if they provide an understandable interpretation of the uncertainty of the results. Example: iterative changing of the estimated data age and subsequent surface calculation of the depth difference of the two survey runs in a profile. The data age with the lowest sum of squares of the deviation is the desired value. The uncertainty is approximately equal to the iteration step size.

The uncertainty of the data age

$$\sigma_{Datenalter} = \frac{1}{(v_2 - v_1)} \times \left(\sigma_{ds}^2 + 2 \times \frac{ds^2}{(v_2 - v_1)^2} \times \sigma_v^2 \right)^{1/2}.$$

For example: v_2 = 4 m/s; v_1 = 2 m/s; length ds = 5 m; σ_v = 0,2 m/s; σ_{ds} = 0,5 m; resulting in a data age of 2,5 seconds with an uncertainty $\sigma_{Data\ age}$ = 0,43 seconds and 68 % certainty probability.

*The shorter the length **ds** and larger the velocity difference, the more precise is the determination of the data age!*

Pitch Angle Calibration on site testing (Fig. 3):

passed over a prominent object at a low rate of speed and store the measurement (speed from GPS);

passed over the same object in the opposite direction at the same speed and store the measurement (speed from GPS);

measured the apparent position shift ds of the object between the two measurement runs;

calculated the systematic deviation from plumb α from the water depth T and the positional shift; using the formula given above, calculated the uncertainty of the calculated angle $\propto$ (result is in radians, to be converted to °);

checked the magnitude of the uncertainty compared to the calculated value;

the pitch angle have been determined at least two times. The parameter have been changed with the approval of the hydrographic surveying circumstances.

As an alternative to this procedure described above, computerized processes have been used when they enable a statistically confident assessment and if they provide an understandable interpretation of the uncertainty of the results. For example: iterative changing of the estimated pitch angle and subsequent surface calculation of the depth difference of *the two measurement runs in a profile. The pitch angle with the lowest sum of squares of the deviation is the desired value. The uncertainty is approximately equal to the iteration step size.*

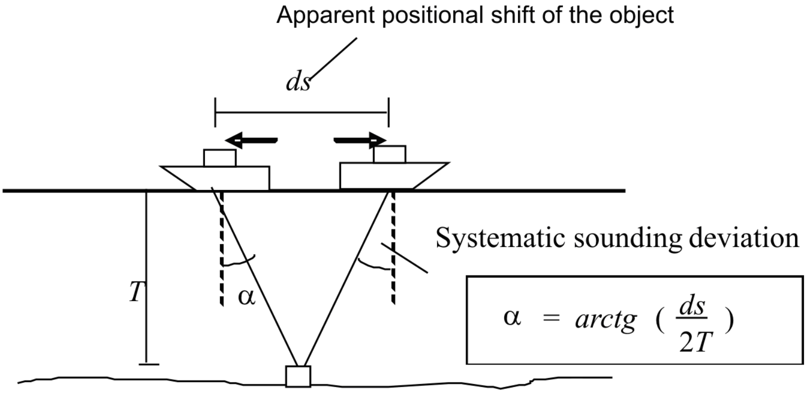

Fig. 3. On site testing of angle calibration

The uncertainty of the pitch angle

$$\sigma_\alpha \cong \frac{1}{(2\times T)} \times \left(\sigma_{ds}^2 + \frac{ds^2}{T^2} \times \sigma_T^2\right)^{1/2}.$$

For example: with a pitch angle α = 5 ° and depth T = 15 m, ds = 2,62 m; assuming that σ_T = 0,10 m and σ_{ds} = 0.25 m, the uncertainty of the pitch angle becomes σ_α = 0,48 ° and 68 % certainty probability.

The more precise the positional shift haave been measured, and the greater the water depth of the object, the more precise is the result. The positional shift measurement is positively influence if the vessel speed is low.

Installed Angle of the Transducers in Multi-beam Systems relative to the Ship's Axis.

The influence of the azimuthal transducer direction on the angular measurement was not be separated from the influence of the compass zero offset and random compass angular measurement errors in a field process. They have met other inseparable influences in the field whicy is:

- positioning errors;
- calibration errors of transducer coordinates.

Therefore, the field process just serve as a transitional solution up to the next calibration.

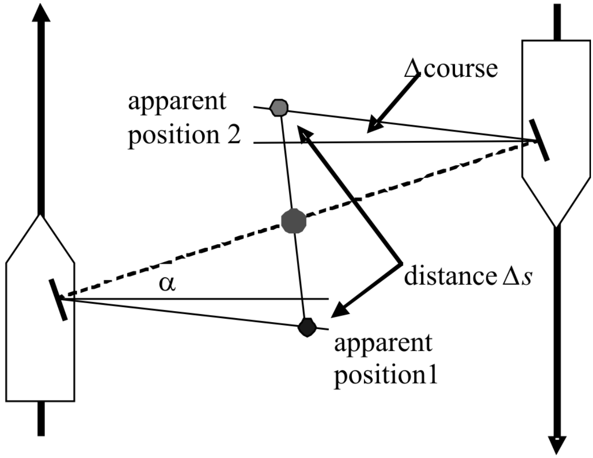

Fig. 4. Calibration in Multi Beam system

Performed the following calibration:

finded a prominent object that they passed over from two sides;

defined two parallel sounding lines at a distance of approximately 5,5 times the water depth, the prominent object was at the same distance to the two sounding lines;

navigated along prescribed sounding line 1 at a constant speed and without making any course corrections, and store the measurement;

navigated along prescribed sounding line 2 at a constant speed and without making any course corrections, and store the measurement;

calculated the distances of the two transducer centers from the prominent obstruction. The parameter sought is the sum of the two distances. When the sounding lines are maintained precisely, this sum is equal to the distance of the two sounding lines;

determined the straight distance between the two apparent positions of the prominent obstruction;

calculated the azimuthal transducer direction and the uncertainty using the formula given below;

the montaged angle have been determined at least two times. New sounding lines are defined for each new determination;

checked the magnitude of the uncertainty compared to the calculated value;

perform points *a*) through, *i*) for each transducer;

the parameter just be changed with the approval of the hydrographic surveying circumstances.

$$\alpha \approx \mathrm{arctg}\left(\frac{\Delta s}{(q_1 + q_2)}\right).$$

The uncertainty of angle α have been estimated as follows:

$$\sigma_\alpha \cong \left(\frac{\sigma \Delta s^2}{(q_1 + q_2)^2} + 2\frac{\Delta s^2}{(q_1 + q_2)^4}\sigma q^2 + \sigma \Delta K^2\right)^{1/2}.$$

For example: at an angle α = 5 ° and depth T = 15 m, and with a 6-fold coverage, Δs_α = 6 * 15 * tg(α) = 7,88 m. The unknown course angle zero offset is 0,2 ° => $\Delta s_{\Delta K}$ = 0,32 m and the total length Δs = 8,20 m. Assuming $\sigma_{\Delta s}$ = 0,75 m and $\sigma_{\Delta K}$ = 0,05 ° and σ_q = 1,5 m, the uncertainty of angle α becomes: σ_α = 0,50 ° and 68 % certainty probability.

At a water depth T = 6,0 m, and with a 6-fold coverage, Δs_α = 3,150 m, $\Delta s_{\Delta K}$ = 0,126 m and the total length Δs = 3,28 m.

Assuming $\sigma_{\Delta s}$ = 0,45 m and $\sigma_{\Delta K}$ = 0,05 ° and σ_q = 1,5 m, the uncertainty of angle α becomes: σ_α = 0,79 ° and 68 % certainty probability.

On site testing. Performed the following calibration:

passed over a flat waterway bottom at an average rate of speed and store the measurement;

passed over the same bottom area in the opposite direction at the same speed and store the measurement;

calculated the outside roll angle error from the deviations of the measurement runs. Repeated the calculation on at least 10 other sections and calculated the average and standard deviation of the individual measurement and of the mean;

checked the magnitude of the uncertainty compared to the calculated mean;

the parameter just have been changed with the approval of the hydrographic surveying manager.

As an alternative to the procedure described above, computerized processes have been used when they enable a statistically confident assessment and if they provided an understandable interpretation of the uncertainty of the results. For example: iterative changing of the estimated roll angle and subsequent surface calculation of the depth difference of the two measurement runs. The roll angle with the lowest sum of squares of the deviation is the desired value. The uncertainty is approximately equal to the iteration step size.

Testing the Transducer System. The transducer system, i.e. the depth measurement, was tested using a reference surface (calibration plate, acoustically unencumbered). In the process, the ship was maintained above the reference surface in as quiet a state , and the measured water depth is compared to the actual water depth with the transducer at the correct depth. The test was performed without positioning.

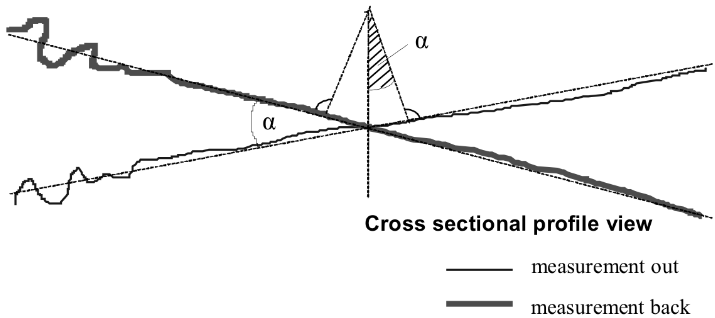

Fig. 5. Roll angle calibration

Perform the following test for transducer:

bring the ship to a quiet, stable position above the reference plate;

determined the water sound velocity and the C-profile using a thermometer and enter the water sound velocity into the depth measurement system;

checktd the transducer depth setting in the depth measurement system;

calculated the current target depth using the gauge reading, the gauge zero and the mean sea level of the reference plate (target depth = mean sea level height of the gauge zero + gauge reading – mean sea level height of the plate);

selected a suitable measurement interval to achieve a sufficient number of measurements;

stored the depth measurements;

depending on the software observe the graph of deviations of the measurements from the target depth;

log the results (for example bitmap of the screen output).

Results the Testing the Measurement System you can see below.

Calibration frequency: 1 = yearly, 2 = twice per year, 0,5 = more frequent.

Directory of valid standpoints not applicable, does not exist. Measurements using a Multi-beam Surveying System**.** Lateral Coverage and Point Density.

Table 1

Result the testing of compass

System	Frequency of Calibration	Permissible tolerance, °
Inclinometer	2	≤ 0,3
Compass	1	≤ 0,5

Table 2

Result the testing of transducer system

System	Frequency of System Testing	Permissible tolerance
Transducer system	1	≤ 0,05 m
GPS receiver with on-board GPS antenna	0,5	≤ 0,05 m
Polar station	0,5	≤ 0,1 m
C probe	2	≤ 3 m/s

Table 3

Conditions of testing

Transducer	Squat, cm	Speed, kn	Load condition, %
all	ca. 15	15	90
–	ca. 10	10	50

Table 4

Result the testing of Calibration Equipment

No.	Location	Target elevation	Notes
Gauge 11	Vilkovo	mean sea level – 1,46	Model exists
High point	11 km	NHN 0,711	Height status 0,711
Gauge 12	02 km	mean sea level – 0,60	Model exists

For multi-purpose sounding, the point density must be at least 3 points within a square surface with a 2 m edge length. For objects, care must be taken that they are sufficiently sounded from both sides by the beams.

Table 5

Result of the conclusion date for Low Danube

Rate	Hydrographic surveying for cartography	Hydrographic surveying in looking for dynamic procedure	Multibeam surveying
Minimum distance, m	0,20	0,20	0,20
Function degree	embankment with changing inclination	embankment with changing inclination	trough/summit
Mesh width, m	10,0	5,0	automatic

Table 6

Result of the conclusion date for Kilia branch (Function: Hyperb. paraboloid. Weighting: max 2 m; min 1 m; 1000:1,4 sectors)

Rate	Hydrographic surveying for cartography	Hydrographic surveying in looking for dynamic procedure	Multibeam surveying
Mesh width, m	2	1	1

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