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CFD SHIP SQUAT DETERMINATION METHOD VALIDATION BY GPS-RTK MEASUREMENTS

ABSTRACT

The paper presents the result of researches aimed to determine squat of ferry Jan Śniadecki in Świnoujście Port with use of CFD methods in compare with real measurements carried out by GPS-RTK methods. The results of validation were presented together with some practical conclusions.

Keywords:
squat, CFD, RTK.

INTRODUCTION

The problems concern with navigational safety in port areas adapted for large ships are very important in waterway design. One of the most important problems on restricted areas is to determine hydrodynamic forces acting on moving ship's hull on restricted water areas. The squat determination during ships movement on restricted water areas is one of the most important problems affecting navigational safety.

The paper presents research results which were aimed to validate the CFD method (Computational Fluid Dynamics) for squat determination. CFD method is nowadays one of the most promising methods in today's ships hydrodynamics but need to be properly validated. Author's research thesis was the question if CFD method could be used for squat determination for practical problems for squat determination and ships manoeuvring safety on restricted water areas.

The validation was based on real experiments carried on the passenger ferry ship Jan Śniadecki manoeuvring on approach to Śwninoujście Port. The squat was determined by very accurate GPS-RTK method.

REAL SQUAT MEASUREMENTS BY GPS-RTK

The measurement device in real experimentations was based on GPS (Global Positioning System) together with very accurate RTK (Real Time Kinematics) with OTF (On The Fly) initialisation. In experiment three RTK receivers was used together with dedicated VHF radio link. One of the receivers was acting as the ground base station. It's position (position Lat: 53°54'58.678''N and Long: 014°15'43.334''E, UTM: N: 5974461m, E: 451530m, for WGS84) was known with high accuracy and RTK corrections was send via radio link to 3 rover receivers on board of the ferry. The RTCM and CMR data transmission format was used. The relative high position of ground base station located at Centre of Creative Work of Maritime University of Szczecin in Świnoujście, Komandorska 5 St assure the high range of corrections transmission at the area of ferries approach [1, 2].

Three rover GPS-RTK receivers with controllers and recorders was set up on Jan Śniadecki ferry (two receivers on bow and one on aft). Such layout of receivers ensures the possibility of determination of all ferry parameters like position, squat, roll, yaw and pitch. The detailed setup of antennas and receivers is presented in fig. 1.

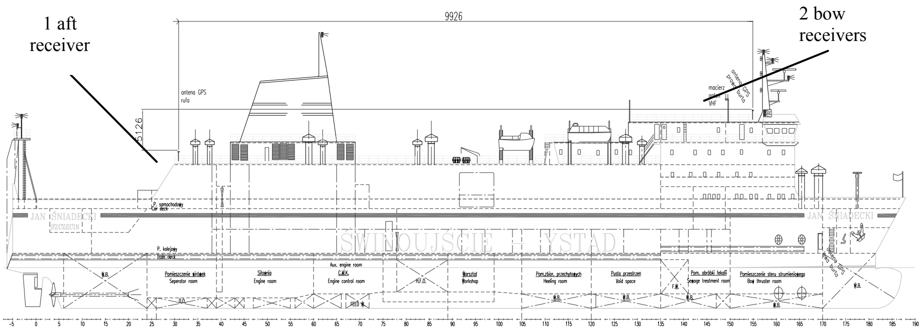


Fig. 1. The horizontal layout of RTK and VHF antennas on m/f Jan Śniadecki [2]

The researches were conducted during 17.05.2006 — 15.07.2006. The data was recorded during entering and leaving the ferry to/from Świnoujście. The research area is presented in fig. 2.

During the departure the receivers was switch on in 3–5 min before unmooring and the data was recorded until the maximum range of transmitted corrections (buoys No. 3–4 for the aft receiver and buoys No. 1–2 for bow receivers). The similar process but in opposite way was conducted during ferry entrance to Świnoujście Port.

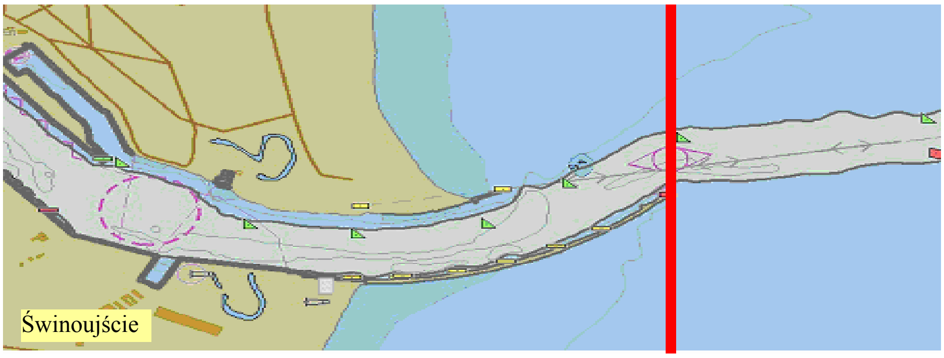


Fig. 2. Research area. The approach area to Świnoujście Port

SQUAT DETERMINATION BY CFD METHOD

To identification of hydrodynamic forces acting on the ship on restricted waters the Computational Fluid Dynamics (CFD) method was used. The commercial program FluentTM was used (fig. 7). The following simplifications were made in restricted area:

- the straight line ship's movement with no change in ships speed parameters was assumed;
- still water, no current and no wave;
- restricted canal with parameters similar to entrance to Świnoujście;
- no ships propeller interaction;
- flat bottom and even embankments;
- no mesh deformations possibility;
- symmetrical shape of water area.

Area model

To properly validate the results of real experiments it was necessary to create detailed model of water area. It was created in scale 1:25,4 based on soundings made in Świnoujście — Szczecin waterway with use of 400 chosen soundings-data points. To assure proper accuracy two models was created: one form approach to breakwater entrance (fig. 3), and other inside the Świnoujście Port (fig. 4).

The following boundary and starting conditions was defined in Fluent CFD program [3, 4, 5]:

- INFLOW: inflow of water speed in mean m/f Jan Śniadecki speed in given waterway area;

— OUTFLOW: outflow of pressure as mean atmospheric pressure;
— PS: in plane of symmetry the conditions of symmetrical flow was defined;
— HULL: wall with defined roughness factor;
— WALLS: side wall with perfect smooth, bottom moving according to water speed flow;
— OYGINAL PLANE VOF: atmospheric pressure.

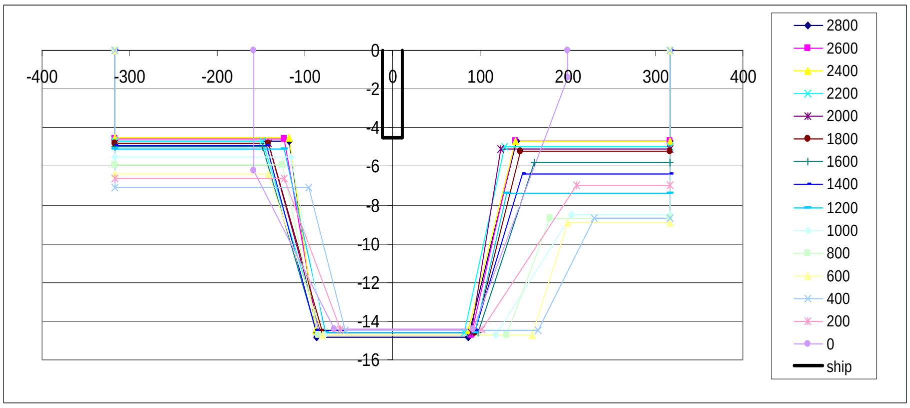


Fig. 3. The applied sections inside the Świnoujście Port

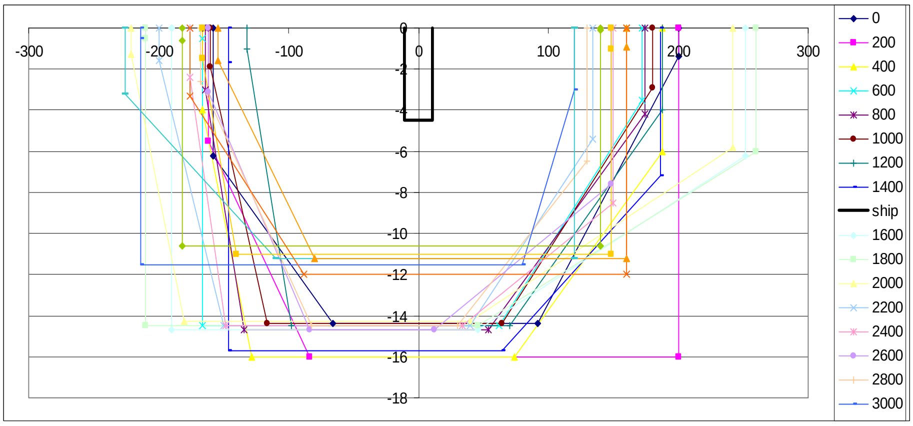


Fig. 4. The applied sections in approach channel to Świnoujście Port

<u>Initial conditions for turbulence are as follows:</u>

The model of turbulence k–ε was defined with initial conditions with use of turbulence intensity and length of mixing calculated by the formula l = 0,07*L equals: I = 2%; l = 0,43 m. The research area is presented in fig. 5.

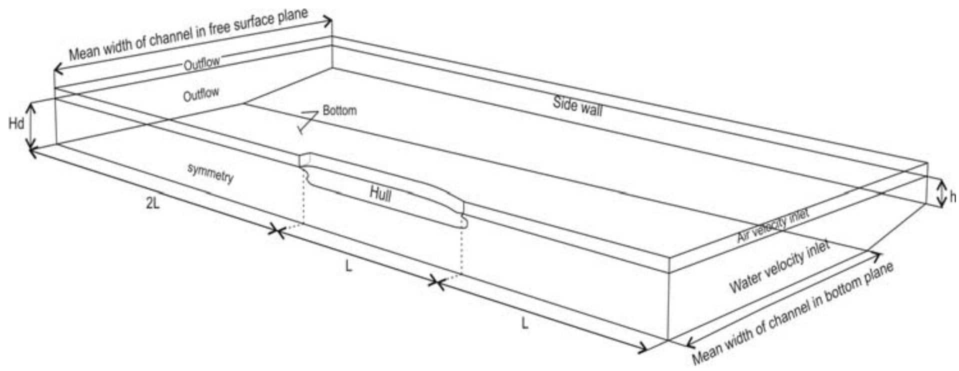


Fig. 5. The domain of the flow of CFD experimentation with given boundary conditions

Ships model

To calculate the squat of ferry Jan Śniadecki the geometry of hull was defined according to table 1.

Table 1. Jan Śniadecki hull parameters

Parameter	Dimension	Model dimension (scale 1:25,4)
Lpp [m]	155	6,10235
B [m]	21,58	0,8496046
T[m]	4,5	0,177165
Cb	0,625	0,625

The structural mesh of Jan Śniadecki was created in next step (fig. 6). It consists of 700 000 of vertexes with logarithmic density increase in perpendicular directions to free surfaces, walls, and hull surface.

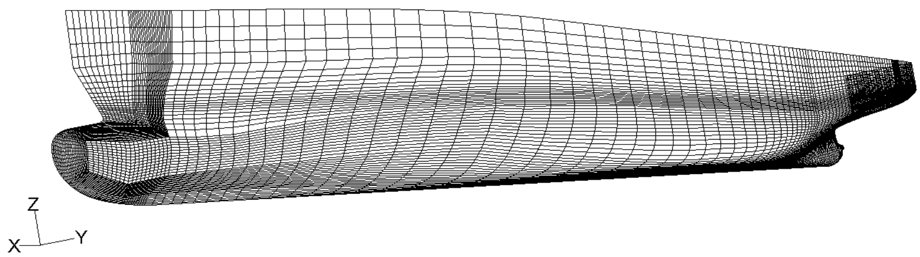


Fig. 6. Applied in CFD Jan Śniadecki ferry hull mesh

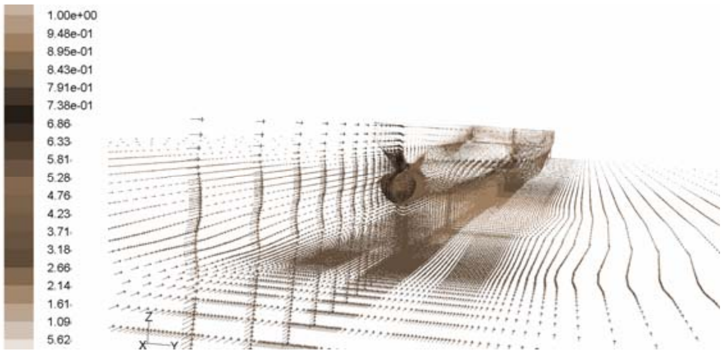


Fig. 7. Speed of water flow [m/s] within distance of 3600 m after passing Świnoujście breakwater (example of calculations by Fluent)

RESULTS

To determine the squat of Jan Śniadecki ferry by means of GPS-RTK measurements the mean draught of ships fore and aft was calculated during passage. In the next step the mean draught was calculated and used to ships squat determination.

To calculate the squat by CFD method the vertical component of force acting on ships hull was used. It was assumed that this force is the sum of static and hydrodynamic displacement which value was changed according to pressures generated on ships hull during ships movement above the bottom.

The results of squat determination of Jan Śniadecki ferry are presents in fig. 8. Additionally the squat calculation results are presented by mean chosen of empirical methods verified in [1].

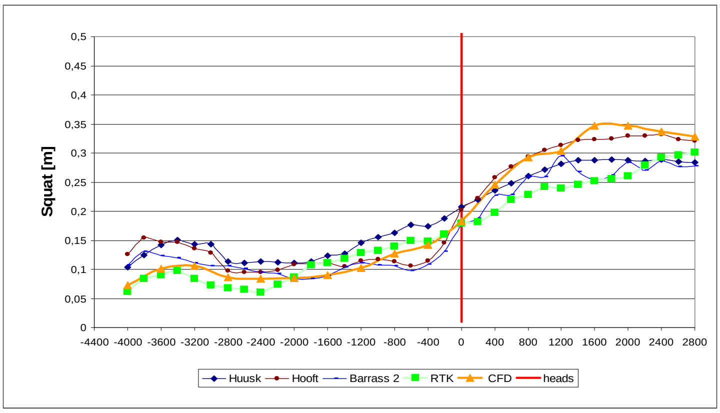
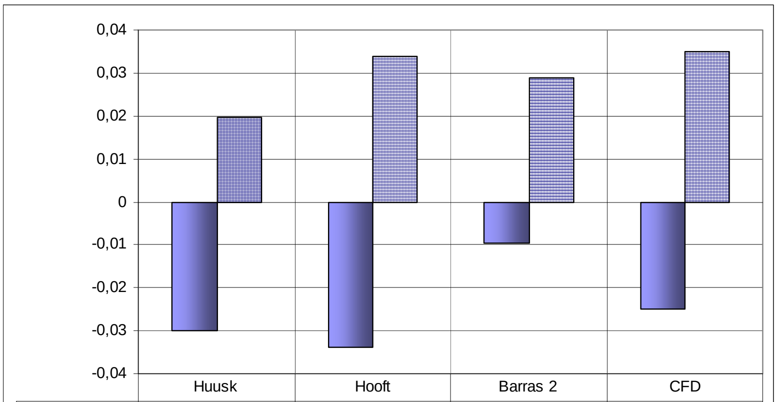


Fig. 8. Comparison of squat calculated by means of CFD method, given empirical methods and real GPS-RTK researches

The comparisons of squat calculations by CFD method with most widely used empirical methods for squat determination are presented in fig. 9.



	Huusk	Hooft	Barras 2	CFD
mean [m]	-0,029924142	-0,033975049	-0,009500057	-0,025060205
stand. dev [m]	0,019550675	0,033953973	0,028964223	0,035095711

Fig. 9. Values of mean and standard deviations of squat determination errors in comparison to the real researches carried out by GPS-RTK

By means of CFD method the wave system could be also calculated. Fig. 10 resent wave system in given waterway sections.

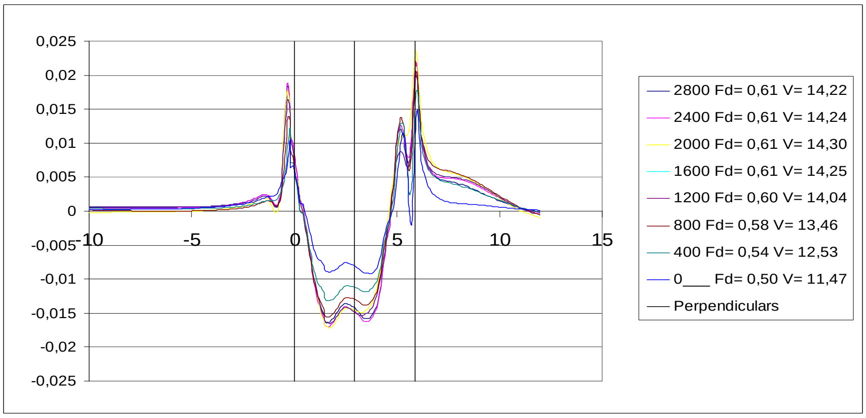


Fig. 10. The wave profiles during CFD simulations in given sections before entrance to Świnoujście scale (1: 25,4)

CONCLUSIONS

The results of CFD method validation by means of real measurements proved possibility of squat modelling.

The values of squat are within 0,075 m to 0,35 m for the ferry Jan Śniadecki during approach to Świnoujśce Port. The accuracy of CFD method is within the range 0,09 m to 0,025 m. Maximum values of squat errors are around 2 km from breakwater. The reason of this phenomenon could be higher speed of ship, difference of waterway shape in this area and CFD method inaccuracies. The CFD method could be use in the future for practical applications.

More accurate mesh of ships and waterway models could be useful for further development of this method and in future to ships hull forces determination for large ships manoeuvring on different water areas.

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