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THE EFFECT ON CONSTANT HEEL ON CIRCULATION OF A VESSEL CALCULATED ON THE BASIS OF INVESTIGATIONS OF M/S "ZIEMIA ZAMOJSKA" MODEL

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ABSTRACT

The article presents modeling research on the M/S "Ziemia Zamojska" reduced model, carried out in an open fresh water area by a team of employees of the Department of Operating of Floating Vessels, Polish Naval Academy, Gdynia. The research involved circulating the model with constant angle of heel on the selected side, and the main engine set to full speed ahead. Using a real ship to carry this type of investigations is risky. It may lead to some failures like e.g. rudder failure, steering gear malfunction, overload and in some circumstances even main engine seizure. For this reason, ships are not tested with the rudder put to starboard or to port at the full speed ahead setting, even during a "Crash Stop" maneuver. However, based on the analysis of accidents at sea, and practical experience, it appears that during real operating conditions of vessels, there may occur situations when, for the sake of safety, the maneuver mentioned above must be carried out. Therefore, the authors had to conduct model tests of a floating vessel for the described case of ship operation

Keywords:

Ship maneuvering, tests of maneuvering properties, reduction model

Research article

INTRODUCTION

Design of ships or marine structures requires a series of specialist analyzes and simulations. The purpose of these activities is to make sure the planned facilities comply with the assumed operational characteristics, and safe performance standards in changing weather conditions at sea [2,6].

Scientific modelling research is not only the basic and universal method used to forecast the dynamic properties of a ship, especially at the design stage, but also has a great significance in scientific and research, both as a method of theory verification, and as an autonomous cognitive method [3,6]. The idea of modelling research assumes making inferences concerning the performance of a real object based on the measurements carried out on a model. The results of such tests are used, among others, for forecasting nautical and maneuvering properties of ships, and other floating objects[1,7].

This article describes modeling research on the M/S "Ziemia Zamojska" reduced model, carried out in an open fresh water area by a team of employees of the Department of Operating of Floating Vessels, Polish Naval Academy, Gdynia. The basic particulars of the ship are as follows:

Lpp = 172 m
B = 23 m
T = 9.85 m
H = 13.90 m
Weight of empty ship: 6 622 T
DWT = 26 706 T
Freeboard : 4.086 m

The main object used in the research was a reduced model of the bulk carrier M/S "Ziemia Zamojska", whose construction was based on the theoretical lines on 1:75 scale [9,11]. The model was studied under non-typical operating conditions. The investigations involved circulating the model with constant angle of heel, and the main engine set to full speed ahead [8,10]. To conduct such investigations only models of floating vessels can be used. Using a real ship to carry this type of investigations is risky as some failures may occur, e.g. rudder failure, steering gear malfunction, overload, and, in some circumstances, even main engine seizure. For this reason, ships are not tested with the rudder put to starboard, or to port at the full

speed ahead setting, even during a "Crash Stop" maneuver. However, under real operating conditions of vessels, there may occur situations when, for the sake of safety, the maneuver mentioned above must be carried out. Therefore, the authors had to conduct investigations using a floating vessel and check the performance of the model for the described case of ship operation.

MANEUVERING TESTS OF MODEL OF M/S "ZIEMIA ZAMOJSKA"

Maneuvering tests of the model of bulk carrier M/S "Ziemia Zamojska" were carried out in freshwater. This required the preparation of measuring equipment, selecting the site and testing methodology. To this end, the model of the vessel was balanced in the laboratory conditions, and proper operation of the sensors used to measure the angle of heel, draft, and propulsion system was verified. To record the positioning of the unit Leica Viva receiver and controller were used, and then the data obtained was processed with the Leica Geo Office software [5]. Changes in the heel of the reduced model in the course of circulation were recorded with a Simex angle of heel meter. During the investigations, the possibilities of using the built-in tilt sensors, and the apparatus recording the model's motion parameters, were also checked. In the experiment the impact of the initial heel of the model on the size and shape of the circulation diameter was investigated. Owing to the use of appropriate measuring devices the necessary information were collected and documented.

DESCRIPTION OF PLACE USED TO CARRY OUT INVESTIGATION OF MODELS

The circulation investigations of the model of "Ziemia Zamojska" with heel were carried out on a freshwater pond in Kosakowo. The total area of the basin is 2550 [m^2], and its average depth is 4 [m].

The research in the basin was carried out in the following weather conditions: NNW wind approx. 0.5-1.0 [m / s], temperature 23 [° C], moderate cloud cover. To measure temperature, wind direction, and speed one used a mobile meteorological station, which offered the capability of monitoring of test conditions.

Figure 1 presents a photo of the water body in which maneuvering invetigations of the model were carried out. To fix the position of the model on the water, and to facilitate the calculation of the position coordinates one made a range light

using Leica Viva GS15 receiver, and Leica Viva CS15 controller. It is marked in the Figure below with numbers 1 and 2. The position fixing accuracy of the range light is 0.004 [m]. The circulations of the model were marked with colors: red to the right, and blue to the left.

Fig. 1 A sattelite photo of the maneuvering area together with the mapped maneuvering range and traces of circulation [14]

MEASURING INSTRUMENTS

The instruments for measuring the angle of heel and draft of the model were fitted in the hull. Immersion sensors were fitted in the bow and stern area of the model. The places where the immersion sensors were fitted are shown in Fig. 2.

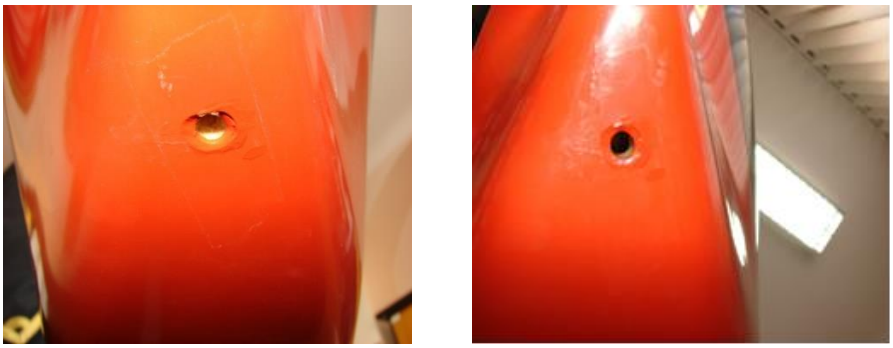

Fig. 2 An arrangement of sensors used to measure draft of ship's model [11]

The results of measurements recorded with the measuring sensors during the circulation of the model of M/S "Ziemia Zamojska" are sent via a remote transmission system, and read out at the CMC shore station. The system's operating range should not exceed 750 m. During the tests, the distance between the model and the recording station was 10 to 40 m, it was within the range of the data transmission system. The selected water area was free of interference from other devices operated in the test area.

The shore station of the measuring system includes the Simex Multicon CMC recorder, radio modem with antenna, gel batteries supplying the station, power supply unit, converter. The 1.5 GB internal memory of the recorder allowed storage of the measurement data. Fig. 3 shows a photo of the shore station.

Fig 3. MultiCon CMC [11]

In order to monitor the current position of the model during circulation, the DGPS RTK system, and mobile devices suitable for the size of the test object, i.e. a 120-channel Leica Viva GS15 receiver, were used. It can receive both GLONASS and GPS signals, and record data having frequency of up to 20 [Hz]. According to the manufacturer's data, the positioning accuracy of the model is as follows:

horizontal: 10 [mm]
vertical: 20 [mm].

A photo of Leica Viva GS15 is shown in Fig.4.

Fig. 4 Leica Viva GS15 [13]

The coordinates of the tracked vessel can be fixed when appropriate algorithms are used in the internal software. The receiver allows tracking satellites over the horizon, working with reference station networks, and quick initialization in the RTK mode. The device can communicate with the controller thanks to the Bluetooth connection installed. [5]

The Leica Viva CS15 controller, shown in Fig. 5, is a modern, powerful portable computer which allows to save the parameters of the observations carried out.

Fig. 5 Leica Viva CS15 Controller [13]

During the preparation for the investigations, both of the above devices were fitted in the holds of the ship's model. The Leica Viva GS15 receiver was fitted in the hold of model No. 4, and the Leica Viva CS15 controller in the hold of the model No. 2. To ensure the model was "on an even keel" position, additional weights were placed in hold 1. Fig. 6 shows a photograph of the ship's model during the maneuvering tests with GPS devices placed inside.

Fig. 6 Ship's model during circulation investigations [4,11]

The photo above shows the investigated ship's model during circulation to starboard. A number of tests were performed during the investigations, and the averaged results are presented in the next chapter.

THE RESULTS OF RESEARCH ON CIRCULATION OF SHIP'S MODEL

The model-based research on circulation was carried out with a constant initial heel to port and starboard. Before starting the tests, it was necessary to take measures to balance the reduced model of the ship, and bring it to a "on an even keel" position In addition, in order to obtain a permanent heel to port or starboard **φ=3.5°**, the ship's model had to be properly ballasted.

The investigations were carried out for circulation to the starboard, and port side. The number of RPM in the main engine was set for Full Speed Ahead, and the rudder deflection was 35 ° on each side ("to port" and "to starboard").

The results of circulation are shown in Figures 7 and 8, and in Table 1, and Table 2, respectively.

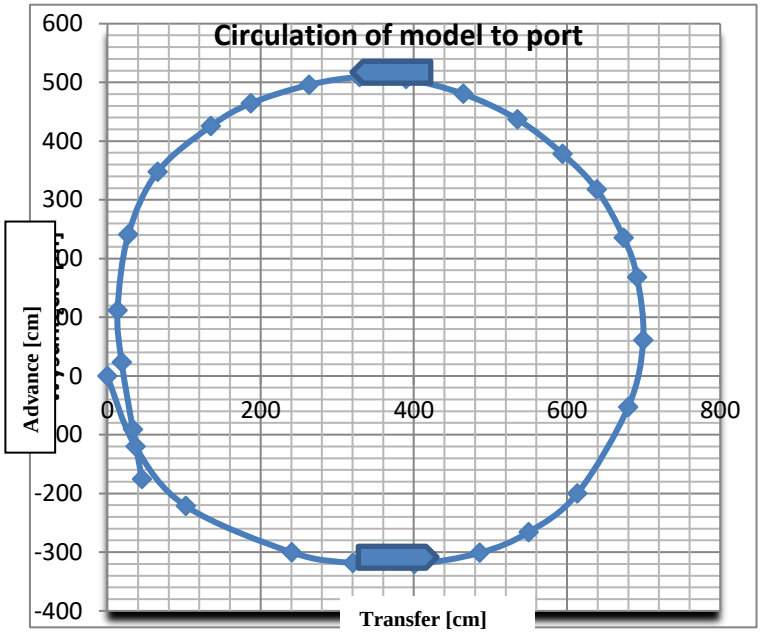

Fig. 7 The results of circulation of the model with heel to port [4]

Table 1. Parameters of circulation presented in Fig. 7

Obiect	Setting	Loading condi-tion	Initial ship speed [kn]	Rudder angle [°]	Diameter [m]	Frontal shift [m]	End time [s]
Tilted model	FSA	Fully loaded	1.4	35	8.2	6.06	26

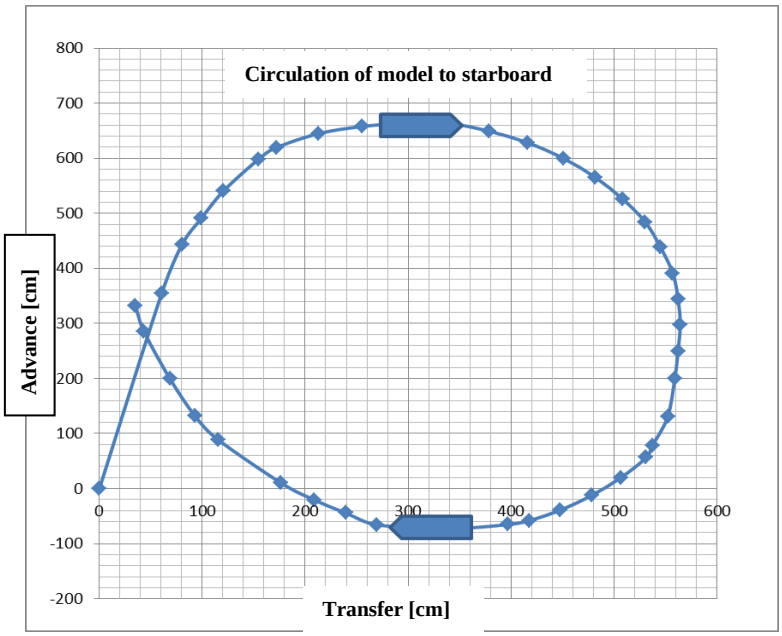

Fig. 8 The results of circulation of the model with heel to starboard [4]

Table 2. Parameters of circulation presented in Fig. 8

Obiect	Setting	Loading condition	Initial ship speed [kn]	Rudder angle [°]	Diameter [m]	Frontal shift [m]	End time [s]
Model with heel	FSA	Fully loaded	1.4	35	7.4	7.06	20

COMPARISION OF THE RESULTS OF CIRCULATION OF THE MODEL WITH INITIAL HEEL, AND WITH NO HEEL

In the next stage of the research, the results of circulation of M/S "Ziemia Zamojska" model were compared, in the same loading condition, loaded with ballast and GPS devices, with no initial heel, and with constant heel to port **φ = 3.5** °.

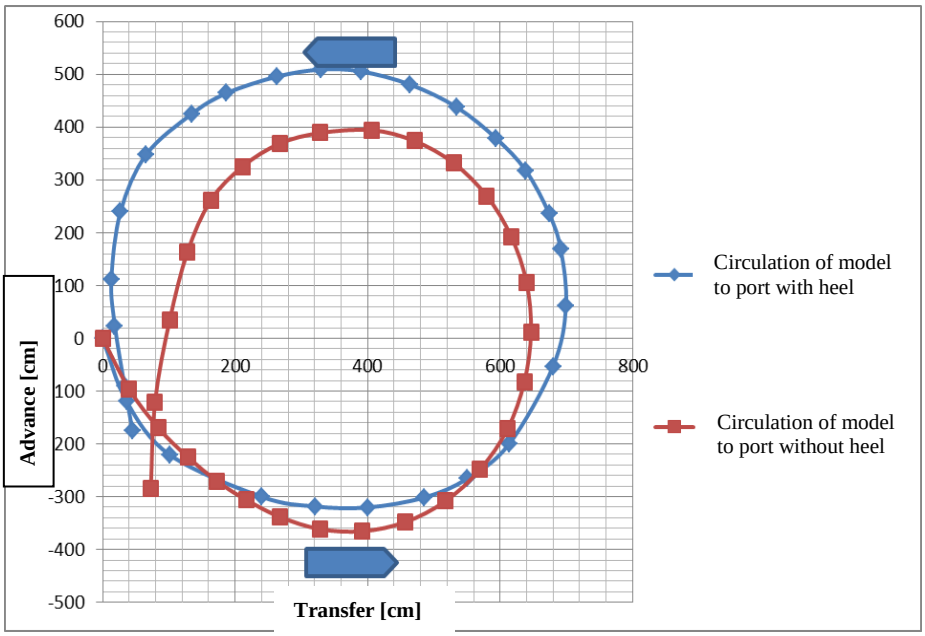

Fig. 9 The results of circulation of the model to port with heeel and with no heel [4]

Table 3. Circulation parameters from Fig. 9 used for comparison

Obiect	Setting	Loading condi-tion	Initial ship speed [kn]	Rudder angle [°]	Diameter [m]	Frontal shift [m]	End time [s]
Model with heel	FSA	Full loading	1.4	35	8.2	6.06	26
Model with no heel	FSA	Full loading	1.4	35	7.4	3.7	59

The circulation of the M / S "Ziemia Zamojska" model to starboard was compared in a similar way. The model was in the same loading condition and was loaded

with ballast and GPS devices. The investigations were carried out for the model with no constant initial heel, and with constant heel to port equal to φ = 3.5 °.

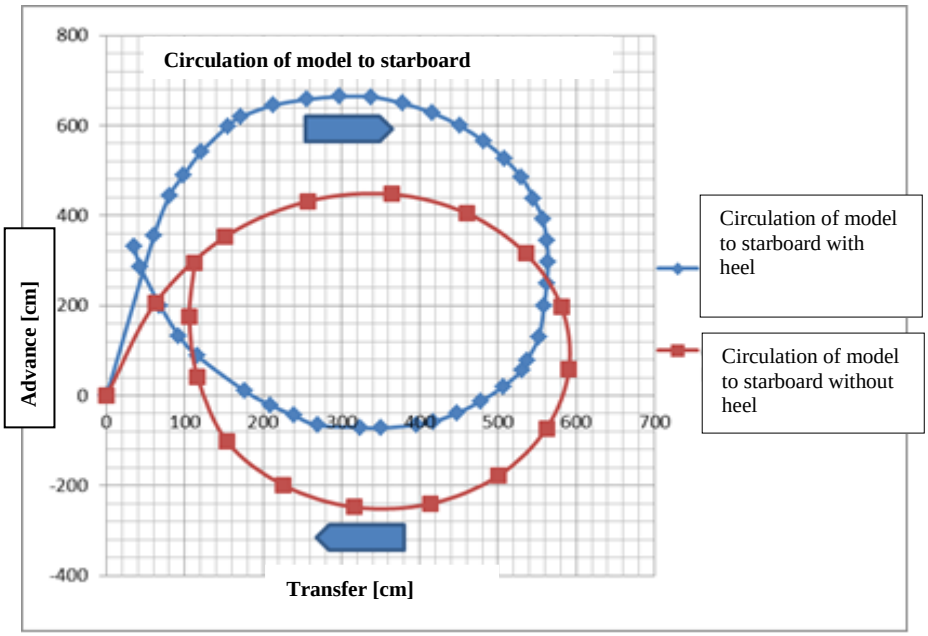

Fig. 10 Comparison of circulation to starboard with no heel and with heel [4]

Table 4. Comparative parameters of circulation wih no heel and with heel.

Obiect	Setting	Loading condi-tion	Initial ship speed [kn]	Rudder angle [°]	Diameter [m]	Frontal shift [m]	End time [s]
Model with heel	FSA	Full loading	1.4	35	7.4	7.06	20
Model with no heel	FSA	Full loading	1.4	35	7.0	4.5	30

During the research, it was noticed that the reduced model of bulk carrier M/S "Ziemia Zamojska" was slightly trimmed by the bow when moving forward, despite the fact that it was with no trim before the start of the research. The forced

constant heel to starboard caused the necessity to correct the course of the tested model using the rudder.

The introduction of a fixed initial angle of heel to port of 3.5° caused the average circulation of the reduced model to increase slightly by 0.8 [m] during circulation to port, and 0.4 [m] during circulation starboard. The cause of this phenomenon was the asymmetrical shape of the immersed part of the hull of the investigated model, and the excessive speed of the model during circulation which disrupted the distribution of the behind propeller flow and its impact on the rudder blade. In addition, the model uses a right-hand propeller generating the tendency to change course to starboard.

During the circulation investigations, the angle of heel of the reduced model was also recorded. The operating centrifugal force, and propeller lateral force had a significant impact on its magnitude. When the model circulated to port it righted due to the centrifugal force action, and the initial constant heel was reduced to zero. However, during a right-hand maneuver, the initial angle of heel 3.5° increased to 10°. During this investigation, the angle of heel increased after covering about a quarter of the distance.

CONCLUSIONS

Summing up the obtained results of the investigations, it can be stated that the angle of heel of the model causes predicted changes in the parameters measured during the circulation maneuver. The main goal of the research was to demonstrate the impact of the initial angle of heel of the investigated model on the magnitude of the circulation radius and angle of heel.

It follows from the analysis of the results of circulation of the model, with and with no heel, that the constant, initial angle of heel of the vessel increases the diameter of circulation during maneuvers both to the starboard and port.

In the case of circulation to port, the introduced constant angle of heel of the model contributed to the reduced angle of heel to zero, and thus to righting the vessel. However, in the case of the right-handed circulation maneuver, a significant increase in the angle of heel of the model up to 10° was recorded. In addition, during this maneuver, the investigated reduced model produced ellipse wake pattern, whereas during the action to maneuver to port the wake had a circle-like pattern.

The duration of the maneuver with no heel was similar to the duration of the maneuver with heel. A slight blowing of wind did not affect the investigations.

The data obtained in the research will be significant for the planning and implementation of the next stage of research in which maneuvering of the M/S "Ziemia Zamojska" model will be assisted by tug models.

REFERENCES

[1.] Duda D., *Manewrowanie statkiem o napędzie mechanicznym*., Wyższa Szkoła Morska, Gdynia 1973

[2.] Gucma M. *Models of maritime safety for development of navigation support systems*. The Archives of Transport 2016, Volume 37, Issue 1.

[3.] Jacyna M.; Wasiak M.; Lewczuk K.; Kłodawski M. *Simulation model of transport system of Poland as a tool for developing sustainable transport*. Archives of Transport 2014, No 3, Volume 31.

[4.] Jarzyna N., *Wpływ przechyłu na cyrkulację jednostki na przykładzie modelu statku m/s "Ziemia Zamojska" praca dyplomowa*, AMW Gdynia 2017

[5.] Mikołajczyk M*., Odbiorniki i kontrolery Leica Viva, Na*wi. Dodatek GNSS geodety. Marzec 2011, nr 1, s,. 14 - 16.

[6.] Mironiuk W. *Model-based investigations on dynamic ship heels in relation to maritime transport safety*. The Archives of Transport 2015, Volume 33, Issue 1.

[7.] Nowicki A*., Wiedza o manewrowaniu statkami morskimi*, Trademar, Gdynia 1999

[8.] Sobieszczański T., *Manewrowanie statkiem morskim*, Tom I, Skrypt niekomercyjny, AMW Gdynia 2014

[9.] Sztolpa M., *Próby manewrowe modelu m/s „Ziemia Zamojska" na wybranym akwenie słodkowodnym oraz ocena ich podobieństwa do wyników prób jednostki rzeczywistej*, Praca dyplomowa, Gdynia 2016

[10.] Wróbel F., *Vademecum nawigatora*, Trademar, Gdynia 2013

[11.] Materiały dot. modelu statku „Ziemia Zamojska" KEJP AMW Gdynia

[12.] http://surveyequipment.com/

[13.] http://www.geoland-surveying.com/

[14.]http://maps.google.com/

WPŁYW STAŁEGO KĄTA PRZECHYŁU NA CYRKULACJĘ STATKU, OKREŚLONY NA PODSTAWIE BADAŃ MODELU M/S „ZIEMIA ZAMOJSKA”

STRESZCZENIE

W artykule przedstawiono opis badań modelowych modelu redukcyjnego statku M/S „Ziemia Zamojska”, przeprowadzonych na akwenie otwartym z wodą słodką przez zespół pracowników Katedry Eksploatacji Jednostki Pływającej AMW w Gdyni. Badania te polegały na wykonaniu cyrkulacji modelu statku ze stałym kątem przechyłu na wybraną burtę, utrzymując nastawę pracy silnika głównego w pozycji cała naprzód (CN). Przeprowadzenie takich testów na rzeczywistym statku jest ryzykowne. Może to doprowadzić do awarii np. steru, maszynki sterowej, przeciążenia, a nawet w szczególnych okolicznościach zatarcia silnika głównego. Z tego powodu na statkach nie prowadzi się testów polegających na wychyleniu steru na burtę przy nastawie CN, nawet podczas manewru „Crash Stop”. Na podstawie analizy wypadków na morzu, oraz z doświadczeń praktycznych, wynika, że podczas rzeczywistej eksploatacji jednostek pływających zdarzają się sytuacje, w których w celu zachowania bezpieczeństwa należy wykonać wymieniony manewr. Wymusiło to na autorach przeprowadzenia badań modelowych jednostki pływającej w opisanym przypadku eksploatacyjnym.

Słowa kluczowe:
Manewrowanie statkiem, badania właściwości manewrowych, model redukcyjny, cyrkulacja