ADVANCED SOFTWARE INSTRUMENTS IN THE STUDY OF SHIPS NAUTICAL QUALITIES

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Abstract: It is well known that the analysis of the consequences that the interaction of the ship's body with the navigation environment has on its behaviour is one of the difficult problems of naval architecture. The responsibility of a naval architect is to develop design methodologies and building technologies that, considering the complex actions of the navigation environment, allow the efficient operation of ships, in accordance with their functionality. For ships operating in the proximity of offshore drilling platforms, more than in the case of others, it is essential to anticipate, well know and control the consequences that the navigation environment has on the general behaviour of the ship. The paper aims to make some contributions to solving the complex problem of the movements of a supply ship (understood as a rigid solid with a complex architecture) in the hydrometeorological conditions of the North Sea and Baltic Sea. The aim is to substantiate a model for the analysis of static and dynamic nautical qualities, computer-assisted by advanced software instruments (AutoHydro and Octopus Office). To exemplify the study, a supply ship built in Tulcea Shipyard was used. The authors were interested in modifying the architecture of the original hull by introducing a cylindrical portion in the stern area of the ship. This architectural choice was justified by the need to provide, on the deck, additional spaces for various equipment intended for work near the offshore drilling platforms, and, below deck, additional storage spaces for various purposes. Using the analysis facilities offered by the two software tools mentioned, the consequences that these changes have on nautical qualities have been analysed (the study exemplifies, with comments and interpretations, the hydrostatic diagram and the stability diagrams). The study was computerized by AutoHydro software for the analysis of static nautical qualities. For the analysis of the dynamic behaviour of the wave profile characteristic of the North Sea, with the help of Octopus software, the oscillatory movements of roll and pitch were analysed, both for the original hull and for the modified version. The paper aimed to support the advantages of computerized studies in the initial design phases, without minimizing the importance of tests in towing tanks or sea trials. For scenarios such as the one proposed in this paper (modification of the length of a ship already built, while maintaining the rest of the initial dimensions) the computer-aided study, with software tools specific to the field of naval engineering and navigation, highlights the following advantages: elaboration of various architectural variants, precision in design, speed in the realization of constructive solutions, simulations of the dynamic behaviour on the wave according to various parameters (draft, speed, encounter angle).
Keywords: naval architecture, platform supply vessel, nautical qualities, comparative study, AutoHydro software, Octopus software

1. INTRODUCTION

Platform Supply Vessels (PSVs) operate in open seas (sometimes severe) near offshore drilling platforms, with an increased risk of collision. This is the reason why they must have an architecture capable of ensuring: good nautical qualities (both static – stability – and dynamic – maneuverability) but also a safe construction, with structural elements that meet the resistance requirements both in open seas and in the vicinity of offshore platforms.

The correlation of the ship's architecture with its functionality and operation was analyzed by Gernez [5], highlighting an aspect that naval architects must consider as a priority – the ability of the onboard personnel to easily, safely and efficiently operate a body with a complex architecture, equipped with various facilities and equipment, in a relatively unpredictable hydrometeorological environment, constantly changing. It becomes evident, therefore, the importance of the architecture of the body and the complexity of the problems that the naval architect must solve.

The problem of the geometry of the ship's hull has always been a concern of naval architects who are constantly looking for solutions to optimize working methods. The use of mathematical methods for generating the shapes of the ship is a first aspect considered by various researchers, knowing the complexity of the lines that make up the body lines. Paper [9] proposes a principle of modeling curves that express the architecture of the ship's hull,

using differential geometry. Recently, Krivoshapko [8] has prospected of the possibility of studying the geometry of the ship's body through analytical methods, proposing six models for generating hydrodynamic surfaces that ensure the optimization of ship shapes and a rationalized geometry. The Radial Basis Function (RBF), as a method with high precision in describing the geometry of the ship [1], represents real progress, highlighting good properties of approximation and interpolation of complex curves in the body lines of the ship.
For the description of the geometry of the ship and the drawing of body lines, various computerized drawing and design tools are used. Of course, Autodesk's products (AutoCAD being the best known) are the ones that have prevailed, and naval architects have immediately become interested in their use. For example, [13] it shows the 3D design of a ship using Autodesk Inventor software that then facilitates the 3D printing of the generated models. Realistic 3D modeling of different ships is being tested by researchers [16] proposing an original dynamic method of generating 3D ship shapes by combining Neural Radiation Field (NeRF) with Signed Distance Field (SDF). To create a quick and easy working environment, Kitamura and his colleagues used Prime Ship-Hull software [6], which includes the dimensions of the ship as the design variables, exploiting the ability of this software to recognize the structural elements of the ship. Papanikolaou [11] has shown an interest in tools and software platforms dedicated to integrated design, an approach that allows the exploration of a huge design space in a relatively short time. Virtual reality testing in naval design was another topic of interest for this author.
Given the multitude of software tools dedicated to naval design that have appeared on the market and considering the deep specialization of some, the problem of data transfer between two typical types of software has become a reality that can no longer be ignored. The authors of the paper [17] analyzed these aspects for data transfer between CAD CATIA and Tribon.
In ship design, for a new series of ships, reverse engineering principles are also used, which involve the redrawing of the shape plans of existing ships, the calculation of hydrostatic curves, the stability calculation, and the compartmentalization of the ship according to the layout plan. It has been proven [12] that the reverse engineering method almost eliminates uncertainty in the design process of a new generation ship.
Chalfant and Chryssostomidis [3] have shown that ship design, being a complex, time-consuming and effort-consuming process, can be streamlined, at least in the preliminary phases, through automation and have proposed, as a solution, the Rapid Ship Design Environment (RSDE) which allows the use of template formats that involve the introduction of a relatively small number of input data.
[14] has highlighted the possibilities of using the MATLAB programming language to analyze the static nautical qualities of the ship (buoyancy and stability), and [7] presents an algorithm related to the On-Board Stability System (OBSS) study.
With reference to dynamic nautical qualities, especially for the analysis of the ship's hydrodynamic performance on calm water and waves, [2] it analyzes the use of advanced numerical methods, mainly computational fluid dynamics (CFD). The possibilities of using the Seakeeping software for the analysis of the ship's behavior on regular and irregular waves (using as input data the main dimensions of the ship and the characteristics of buoyancy and stability) are illustrated by [2]. The software implements functions for approximating the amplitude characteristics of roll, pitch and gyration movements, developed by the author through artificial neural networks.
Sometimes, the operating needs of ships involve modifications (even structural ones in some situations), modernizations or reconversions. It is well known that ship design and shipbuilding are resource-intensive industrial processes: long time for all processes to be carried out; huge financial funds for the purchase of materials and equipment but also for the payment of salaries; large numbers of specialized personnel and huge consumption of labor.
Software licenses dedicated to the marine industry are used with great interest because they offer the possibility of simulations and estimations before the decision to carry out the design and construction processes. Indeed, simulations do not provide an exact solution, but errors are acceptable and offer the opportunity for a correct decision.
The paper aims to emphasize the advantages offered by working with various software licenses specific to marine engineering (meaning AutoShip [18] and Octopus Office [19]). The authors started from a reference ship (PSV type) built in the Tulcea Shipyard, Romania [17], for which the length has been modified (by 2 [m]) through identical multiplication of the constructive shape of the transverse-vertical section in the stern of the ship. The purpose of the simulation was to verify how this constructive decision could modify the nautical qualities of the ship.

2. MATERIALS AND METHODS

The algorithms for studying the ship's nautical qualities are well established in the literature and the authors considered that only a brief illustration of this aspect is sufficient.

Buoyancy is the property of the ship to float (to keep itself at the surface of the water – in the case of surface vessels, and respectively to maintain itself at a certain required depth – in the case of submersibles) [10]. Regarding buoyancy, mechanical equilibrium conditions are relevant, and they take into account the displacement and the Archimedes buoyant forces. To analyse this naval quality, it is important to know the displacement distribution diagram and hydrostatic diagram.
Stability is the property of the intact ship to return to its original equilibrium position after the disappearance of the cause that disturbed its original condition [10]. It is the transversal stability that can usually raise problems. Quantities that define initial transversal stability are elevation of the transverse metacenter $\overline{KM}_T$ [m]; transverse metacentric radius, $\overline{BM}_T$ [m]; transverse metacentric height, $\overline{GM}_T$ [m]. Also, it is essential to know the metacentric stability formula

$$M_S = \Delta \cdot \overline{GM_T} \cdot \varphi = \Delta \cdot (\overline{BM_T} - a) \cdot \varphi \quad [kNm] \tag{1}$$

where: M_S – transverse stability moment [kNm]; Δ - displacement force [kN]; φ – transverse angle of inclination [deg]; a – distance between the center of gravity and the buoyancy center of the hull.
Quantities that define stability at large angles of transversal inclination are:

- the arm (or lever) of static stability, l_S [m], given by the relation

$$l_S = y_{B_\varphi}\cos\varphi + \left(\overline{KB}_\varphi - \overline{KB}\right)\sin\varphi - a\sin\varphi \quad [m] \tag{2}$$

where: y_{B_φ} and $\overline{KB}_\varphi$ represent the coordinates of the buoyancy center of the hull, for the transverse inclined flotation

- the transverse stability moment or transverse restoring moment, $\vec{M}_s$, for which the next equation is valid:

$$\vec{M}_S = \Delta l_S \vec{i} \quad [kNm] \tag{3}$$

The rotation around the longitudinal axis, called transverse oscillation or roll motion, is the periodic movement that the ship, considered as a rigid body, performs around the central longitudinal axis of its mass inertia, under the action of disturbance and resistance moments of the navigation environment [10]. The differential equation of damped transverse oscillations on calm water is

$$I_{xx1}\ddot{\varphi} + 2N_\varphi\dot{\varphi} + \Delta \cdot \overline{GM}_T\varphi = 0 \tag{4}$$

where: $\dot{\varphi}$ – angular velocity [deg/s]; $\ddot{\varphi}$ – angular acceleration [deg/s^2]; I_{xx1} – momentum of inertia calculated in relation with the central longitudinal axis of the mass inertia [tm^2]; N_φ – proportionality factor of the moment of resistance forces with angular velocity [tm^2/s]
The rotation around the transverse axis, called longitudinal oscillation or pitch motion, is the periodic movement that the ship, considered as a rigid body, performs around the central transverse axis of its mass inertia, under the action of disturbing and resistance moments of the navigation environment [10].
The differential equation of damped longitudinal oscillations in calm waters is

$$I_{yy1}\ddot{\theta} + 2N_\theta\dot{\theta} + \Delta \cdot \overline{GM}_L\theta = 0 \tag{5}$$

where: $\dot{\theta}$ – angular velocity [deg/s]; $\ddot{\theta}$ – angular acceleration [deg/s^2]; I_{yy1} – momentum of inertia calculated in relation to the central transversal axis of the mass inertia [tm^2]; N_θ – proportionality factor of the moment of resistance forces with angular velocity [tm^2/s]

The general equation of motion of the ship, in real sea, in vector version is [4]

$$M_\eta(\eta)\ddot{\eta} + C_\eta(v_r,\eta)\dot{\eta} + D_\eta(v_r,\eta)\dot{\eta} + g_\eta(\eta) = \tau_{M\eta} + \tau_\eta \tag{6}$$

where: $\boldsymbol{\nu_r} = \boldsymbol{\nu} - \boldsymbol{\nu_c}$ represents the relative velocity vector; $\boldsymbol{\nu}$ – the general speed vector of the vessel; $\boldsymbol{\nu_c}$ – the general velocity vector of the marine current; $\boldsymbol{\eta}$ – the position and orientation vector of any point, belonging to the vessel; $\boldsymbol{M_\eta}$ – the inertia matrix of the mass of the vessel and the inertia of the additional water masses; $\boldsymbol{C_\eta}$ – the complementary matrix for the motion of the vessel and the additional water masses; $\boldsymbol{D_\eta}$ – the damping matrix determined by the dynamic action of the surface of the water through which the vessel moves; $\boldsymbol{g_\eta}$ – the generalized vector of restoring forces and moments; $\boldsymbol{\tau_{M\eta}}$ – the generalized vector of the disturbing forces and moments generated by the marine currents and waves on the wet surface of the hull, respectively the action of the wind on the sail surface of the vessel; $\boldsymbol{\tau_\eta}$ – the generalized vector of disruptive forces and moments due to command and maneuvering operations performed with the help of propulsion and steering installations.

When writing the equation, the following were taken into consideration: the analysis of the interdependent phenomena and the changes generated by external disturbing factors; using the principle of superposing effects in assessing the irregularity of the navigation environment; applying modern analytical mechanics to determining the matrices: the mass inertia of the ship, complementary to the movement of the ship, the additional masses of water; adaptation and refinement of the strip theory for use in solving the problems raised by determining the hydrodynamic coefficients.

For the case study, courtesy of the Tulcea Shipyard, Romania [17], the PSV 09 CD vessel was used. The main dimensions of the reference vessel are L = 52 [m]; B = 11 [m]; T = 5 [m]. The ship was designed and equipped for the supply of marine platforms, having an unlimited navigation area. The ship can carry cargo on the main deck, liquid bulk goods, solid bulk goods, pipes, and various technical equipment.

To carry out the study, it was necessary to use the body plane and the offset table as input data for the software licenses used and which allowed the geometric modeling of the ship in AutoShip Software.

Because the paper aims to highlight the advantages of computerized studies in the initial design phases (without minimizing the importance of tests in towing tanks or sea trials), the two software licenses used will be briefly presented below: AutoShip respective Octopus Office.

AutoShip software analyzes the static nautical qualities (buoyancy and stability) of any type of floating body. ModelMaker component of the AutoShip software allows configuration of ship geometry.

Autohydro is the component used to perform the calculations, which are finalized by visualizing the straight-body diagrams.

Octopus Office software allows assisted study of the ship's behavior on waves, in real navigation conditions (based on ship geometry, provides creation of 2D hydrodynamic databases, generates various loading conditions, develop the wave specter and Response Amplitude Operator (RAO) of the ship).

3. RESULTS AND DISCUSSIONS

3.1. Ship geometry analysis

The "Locus" command in ModelMaker serves as a fundamental tool for defining the geometry of a vessel's structure, particularly when working with data from a table of offsets.

The "Fill" command is employed to enhance the precision of the model by introducing additional spacing between the couples. In this case, a spacing of 0.5 mm was specified. This refinement process significantly increases the resolution of the model, resulting in a total of 128 defined couples.

Figure 1 shows the 3D model of the reference ship after completing the commands in the ModelMaker component of the AutoShip software.

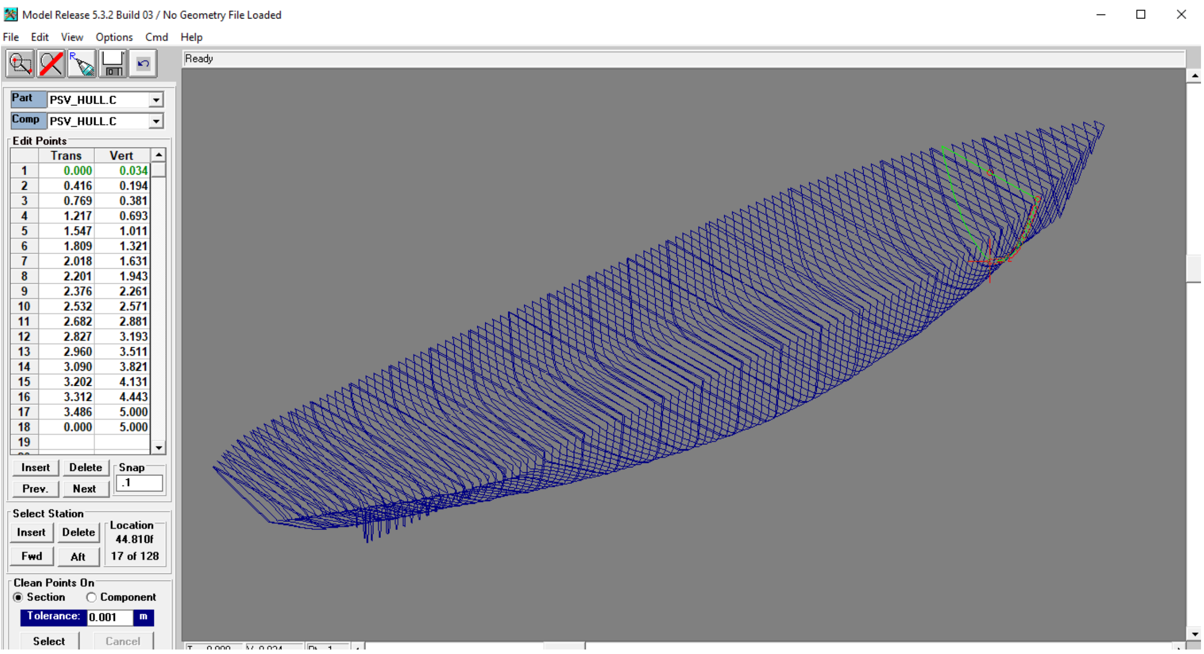


Fig. 1. Reference ship geometry

In the same manner was generated the geometry for the modified ship (Figure 2).

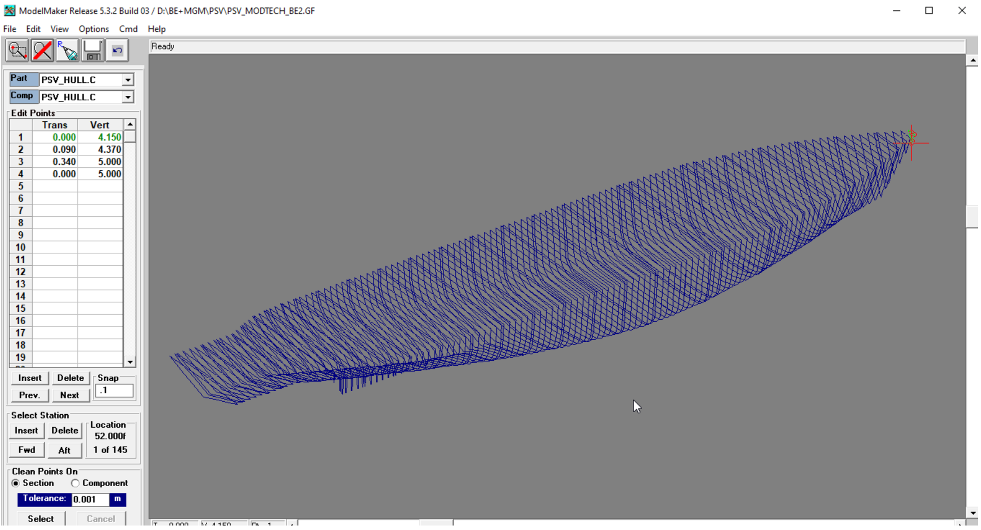


Fig. 2. Modified ship geometry

3.2. Buoyancy analysis

The hydrostatic calculation was made using the AutoHydro module of the AutoShip software. The hydrostatic calculus for the reference ship is illustrated in Table 1, the last line highlighting the numerical values of the characteristic quantities for the full-loaded ship.

Table 1. Hydrostatic properties of the reference ship, made using the AutoHydro component of AutoShip software

$T[m]$	$\Delta[t]$	$x_B[m]$	$z_B[m]$	$x_F[m]$	$TPC[^t/_{cm}]$	$MTC[^{tm}/_{cm}]$	$KM_L[m]$	$KM_T[m]$
0.500	80.705	28.612	0.301	28.371	2.317	264.474	187.743	15.583
1.000	213.381	28.241	0.586	27.649	2.936	431.301	115.799	9.451
1.500	371.638	27.810	0.871	26.837	3.375	594.093	91.583	7.250
2.000	549.476	27.373	1.157	26.085	3.732	758.043	79.036	6.210
2.500	744.397	26.934	1.444	25.293	4.068	942.793	72.559	5.695
3.000	956.404	26.473	1.735	24.418	4.412	1160.753	69.531	5.469
3.500	1185.462	25.992	2.028	23.563	4.747	1404.522	67.877	5.382
4.000	1431.221	25.501	2.324	22.740	5.078	1671.814	66.921	5.400
4.500	1691.891	25.033	2.621	22.256	5.331	1886.351	63.875	5.469
5.000	1966.298	24.670	2.886	22.078	5.498	2030.250	60.091	5.552

Figure 3 illustrates the hydrostatic diagram (generated with the AutoHydro component of the AutoShip software) for the reference ship.

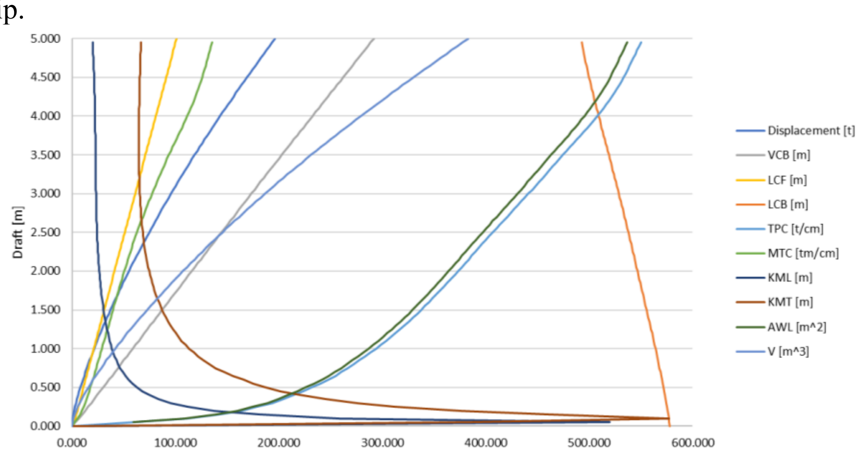


Fig. 3. Hydrostatic diagram for the reference ship

The hydrostatic calculus for the modified ship is illustrated in Table 2, the last line highlighting the numerical values of the characteristic quantities for the full-loaded ship.

Table 2. Hydrostatic properties of the modified ship, made using the AutoHydro component of AutoShip software

$T[m]$	$\Delta[t]$	$x_B[m]$	$z_B[m]$	$x_F[m]$	$TPC[^{t}/_{cm}]$	$MTC[^{tm}/_{cm}]$	$KM_L[m]$	$KM_T[m]$
0.500	80.665	28.611	0.301	28.370	2.316	264.345	187.743	15.581
1.000	213.337	28.240	0.586	27.650	2.936	431.482	115.871	9.453
1.500	371.584	27.809	0.871	26.838	3.375	594.056	91.590	7.252
2.000	549.417	27.373	1.157	26.087	3.731	757.782	79.017	6.210
2.500	744.314	26.934	1.444	25.293	4.068	942.803	72.568	5.696
3.000	956.323	26.473	1.735	24.418	4.412	1160.826	69.541	5.469
3.500	1185.384	25.992	2.028	23.563	4.747	1404.540	67.882	5.382
4.000	1433.187	25.458	2.327	22.111	5.194	1827.963	73.071	5.402
4.500	1704.200	24.813	2.633	20.816	5.626	2256.443	75.855	5.504
5.000	2498.927	24.234	2.910	20.131	5.920	2543.731	74.190	5.649

Figure 4 illustrates the hydrostatic diagram (generated with the AutoHydro component of the AutoShip software) for the modified ship.

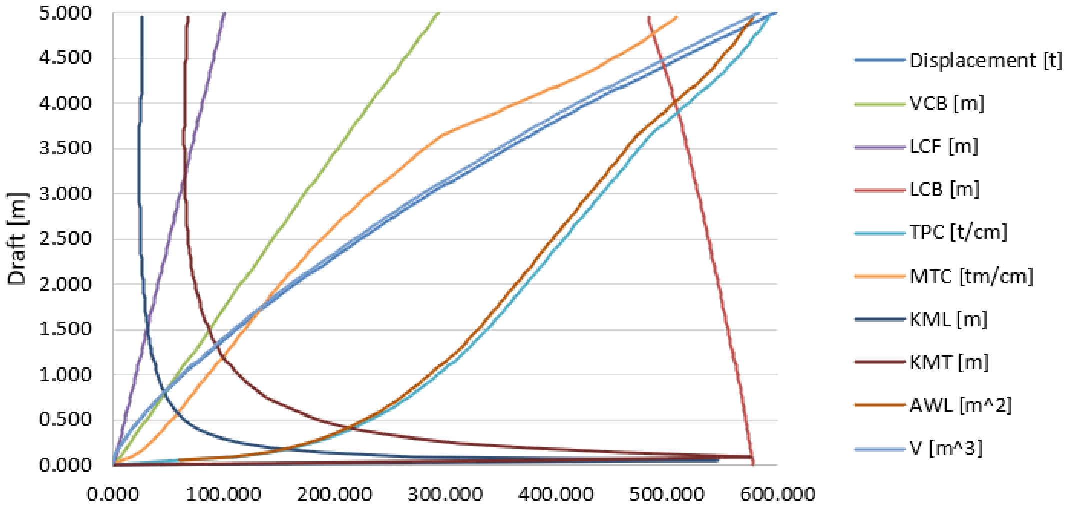


Fig. 4. Hydrostatic diagram for the modified ship

In both Figures 3 and 4, the plotted hydrostatic data are shown, with each element represented at different scales for clarity.
The diagram highlights significant increases in displacement, volume (V), waterplane area (AWL), vertical center of buoyancy (VCB), longitudinal center of flotation (LCF), tons per centimeter immersion (TPC), and moment to change trim (MTC) as the draft increases. In contrast, a slight decrease in the longitudinal center of buoyancy (LCB) is observed as the draft increases. For the longitudinal and transverse metacentric heights (KML and KMT), the diagram shows an exponential decrease, starting from high values at shallow drafts and progressively diminishing as the draft increases.
These trends are critical for understanding the vessel's stability and hydrostatic behavior under varying loading conditions.

3.3. Stability analysis

The calculation for stability analysis was performed using the AutoHydro module of AutoShip software.
Figure 5 illustrates the static stability diagram. In the calculations, the ship was considered to be fully loaded, having a displacement of 1966.298 [t] and the elevation of the gravity center of 4 [m]. The numerical results indicate that the maximum value for the stability arm is 2.619 [m], which is reached for an angle of 38.75 [deg].
Figure 6 illustrates both the numerical values (on the left side) and the static stability diagram (on the right side).

In the calculations, the ship was considered to be fully loaded, having a displacement of 2498.927 [t] and the elevation of the gravity center of 3.5 [m].
The numerical results indicate that the maximum value for the stability arm is 1.661 [m], which is reached for an angle of 30.00 [deg].

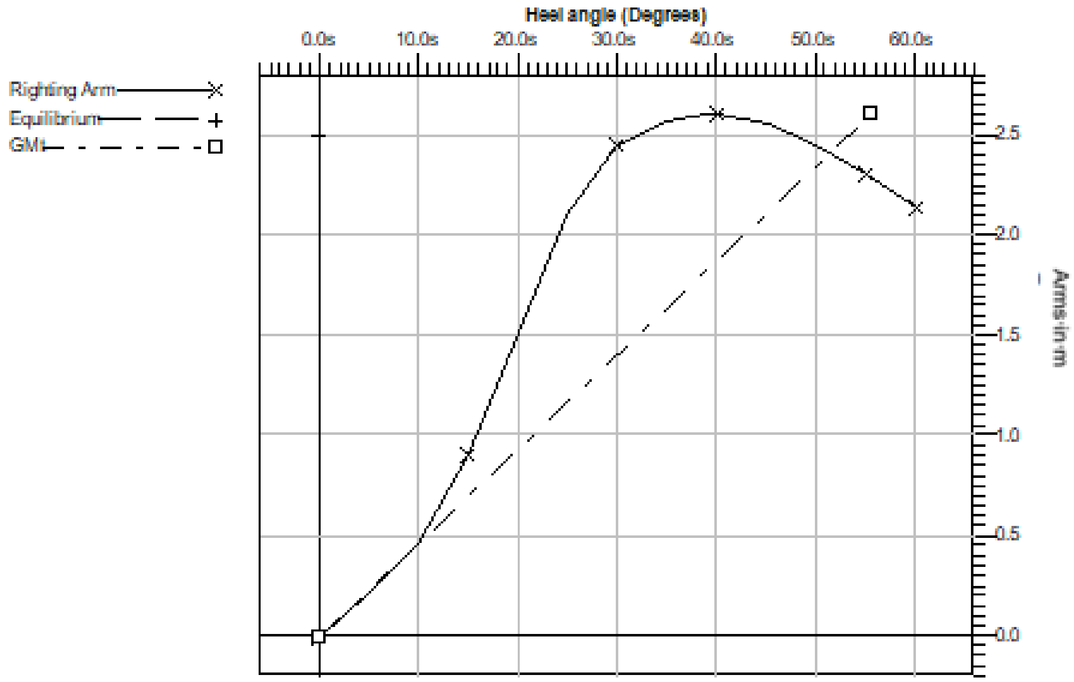


Fig. 5. Static stability diagram for the reference ship

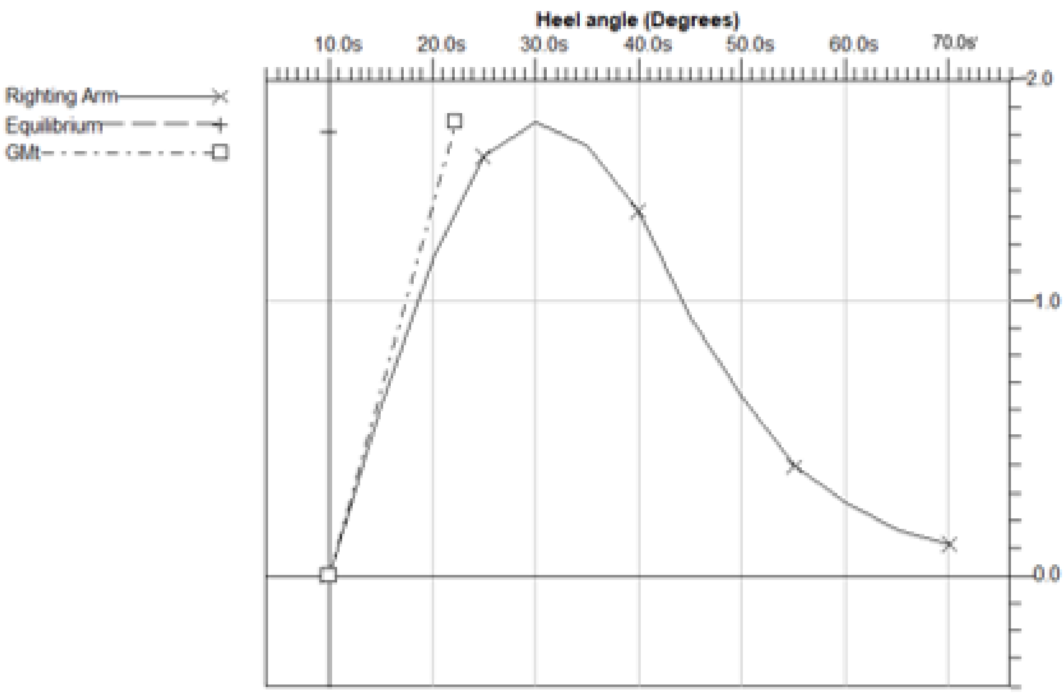


Fig. 6. Static stability diagram for the modified ship

It is recommended that ships have positive initial stability, with the center of gravity being positioned above the center of the hull and below the transverse metacenter (Figure 7).

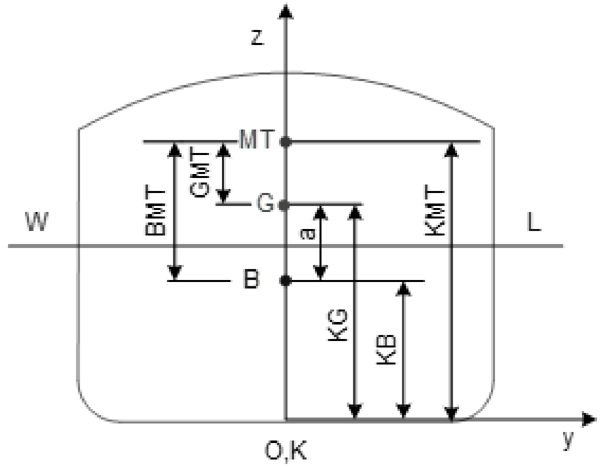
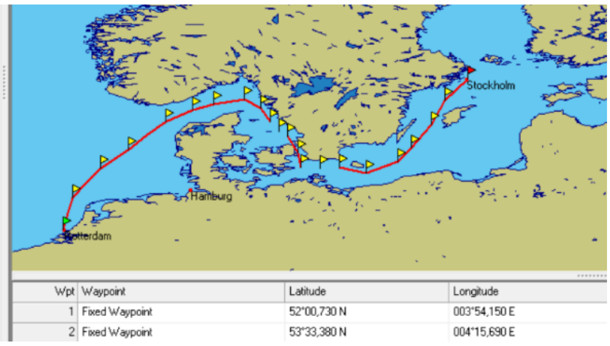


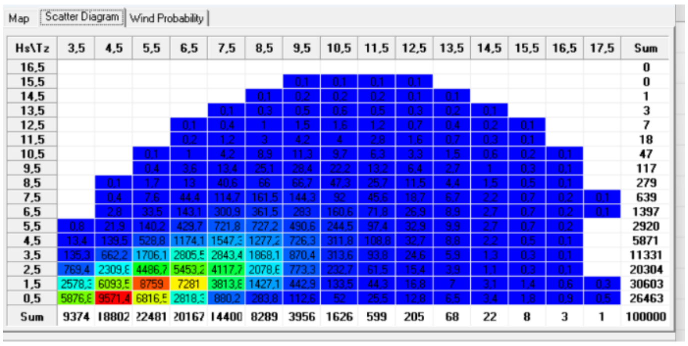
Fig. 7. Recommended positioning for B and G

For the reference vessel,
$\overline{KM_T} = 5.552$ [m] $\overline{KG} = 3.7$ [m]
therefore,
$\overline{GM_T} = \overline{KM_T} - \overline{KG} = 5.552 - 3.7 = 1.852$ [m]
For the modified vessel
$\overline{KM_T} = 5.649$ [m] $\overline{KG} = 4.2$ [m]
therefore,
$\overline{GM_T} = \overline{KM_T} - \overline{KG} = 5.649 - 4.2 = 1.449$ [m]
A reduction in the height of the transverse metacentric of 0.4m is observed.

3.4. Simulation of motions in real navigation conditions

To study the ship's behavior in real conditions of navigation, the Octopus Office license was used.
For both the reference vessel and the one whose length has been modified, in the direction of increase, by 2 [m], the navigation route has been established in the North Sea and Baltic Sea.
Figure 8 illustrates the navigation path and distribution chart for the 100,000 recorded waves (depending on the ratio of significant height of the wave to zero-crossing period).





Hs\Tz	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	Sum
16,5																0
15,5							0,1	0,1	0,1	0,1						0
14,5						0,1	0,2	0,2	0,2	0,1	0,1					1
13,5					0,1	0,3	0,5	0,6	0,5	0,3	0,2	0,1				3
12,5				0,1	0,4	1	1,5	1,6	1,2	0,7	0,4	0,2	0,1			7
11,5				0,2	1,2	3	4,2	4	2,8	1,6	0,7	0,3	0,1			18
10,5			0,1	1	4,2	8,9	11,3	9,7	6,3	3,3	1,5	0,6	0,2	0,1		47
9,5			0,4	3,6	13,4	25,1	28,4	22,2	13,2	6,4	2,7	1	0,3	0,1		117
8,5		0,1	1,7	13	40,6	66	66,7	47,3	25,7	11,5	4,4	1,5	0,5	0,1		279
7,5		0,4	7,6	44,4	114,7	161,5	144,3	92	45,6	18,7	6,7	2,2	0,7	0,2	0,1	639
6,5		2,8	33,5	143,1	300,9	361,5	283	160,6	71,8	26,9	8,9	2,7	0,7	0,2	0,1	1397
5,5	0,8	21,9	140,2	429,7	721,8	727,2	490,6	244,5	97,4	32,9	9,9	2,7	0,7	0,2		2920
4,5	13,4	139,5	528,8	1174,1	1547,[illegible]	1277,2	726,3	311,8	108,8	32,7	8,8	2,2	0,5	0,1		5871
3,5	135,3	662,2	1706,1	2805,[illegible]	2843,4	1868,1	870,4	313,6	93,8	24,6	5,9	1,3	0,3	0,1		11331
2,5	769,4	2309,[illegible]	4486,7	5453,2	4117,7	2078,[illegible]	773,3	232,7	61,5	15,4	3,9	1,1	0,3	0,1		20304
1,5	2578,[illegible]	6093,[illegible]	8759	7281	3813,[illegible]	1427,1	442,9	133,5	44,3	16,8	7	3,1	1,4	0,6	0,3	30603
0,5	5876,[illegible]	9571,4	6816,[illegible]	2818,[illegible]	880,2	283,8	112,6	52	25,5	12,8	6,5	3,4	1,8	0,9	0,5	26463
Sum	9374	18802	22481	20167	14400	8289	3956	1626	599	205	68	22	8	3	1	100000

Fig. 8. Navigation route

Octopus Office license permits simulation the wave specter and calculating the ship response (RAO spectrum) to wave action.
The simulation for the reference ship suggests, for an envelope of the ship's travel speeds (2.8 and 8.3 [Kn]) and a heading of 90 [deg], an amplitude of roll motion of 10.6 [deg] for a wave frequency of 1.75 [rad/s] (Figure 9).

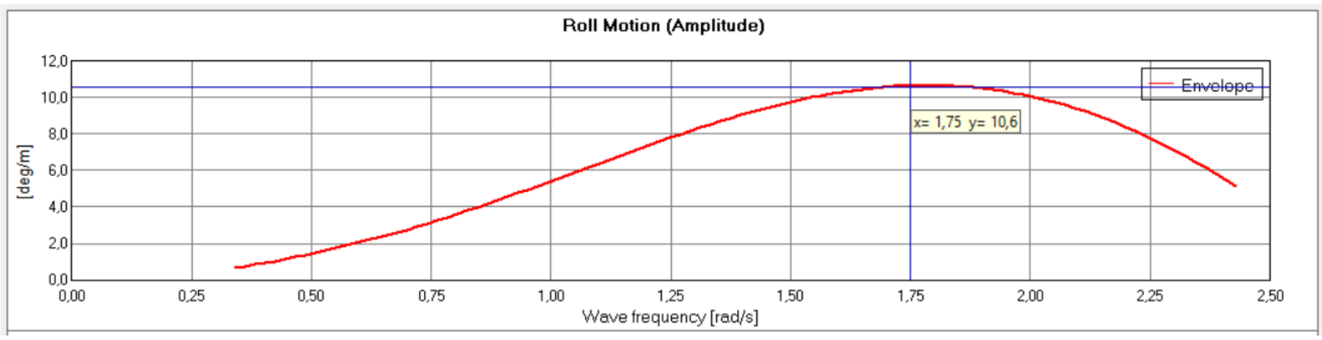


Fig. 9. Roll motion for the reference ship

The simulation for the reference ship suggests, for an envelope of the ship's travel speeds (2.8 and 8.3 [Kn]) and a heading of 90 [deg], also indicates an amplitude of pitch motion of 0.555 [deg] for a wave frequency of 1.40 [rad/s] (Figure 10).

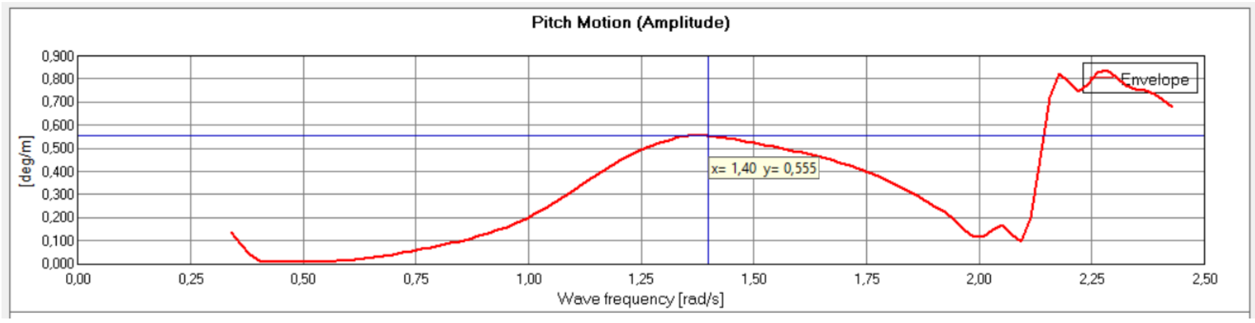
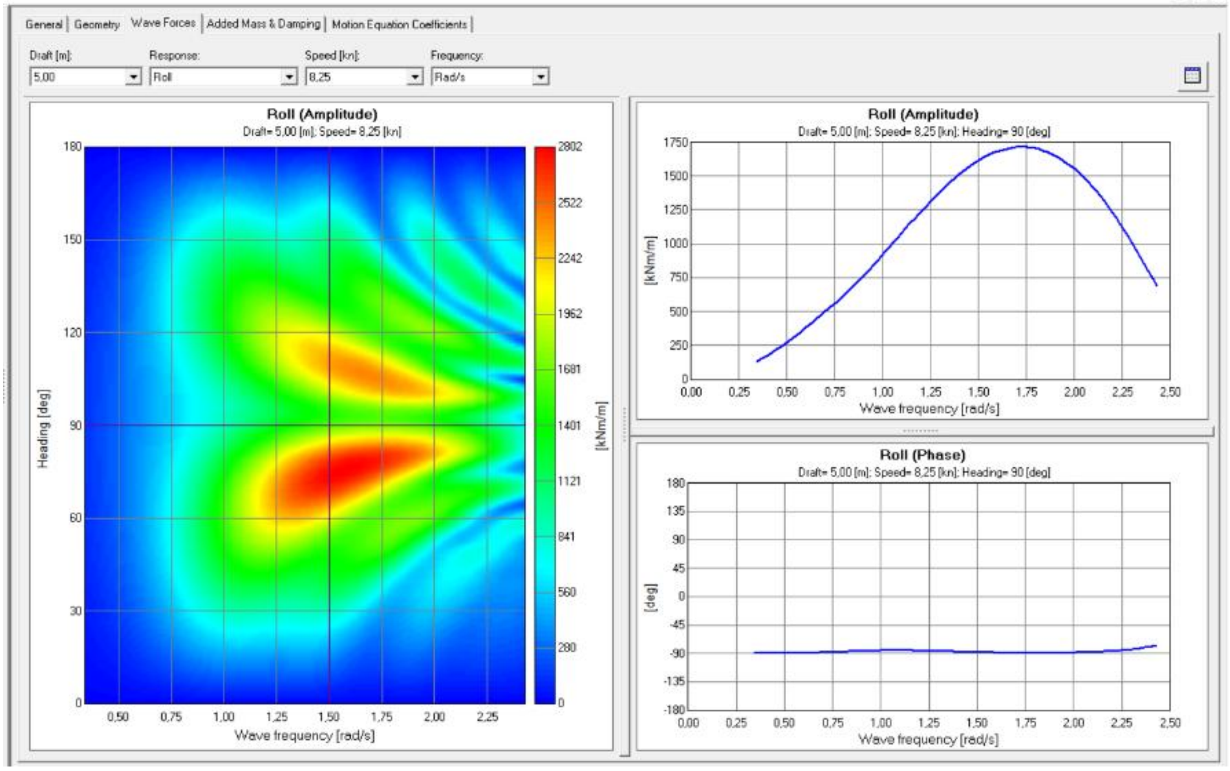


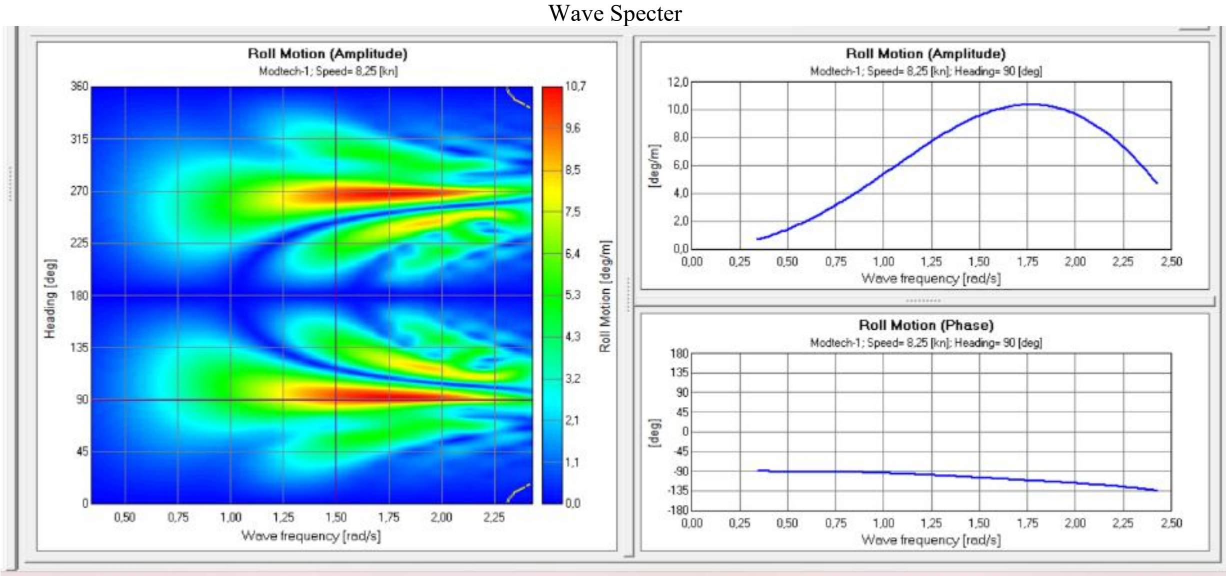
Fig. 10. Pitch motion for the reference ship

Table 3 presents, for the reference ship, some suggestive situations for these two specters – roll and pitch motions were emphasized.

Table 3. Wave specter and RAO specter for the reference ship (Draft 5 [m]; Speed 8.25 [Kn]; Heading 90 [deg])

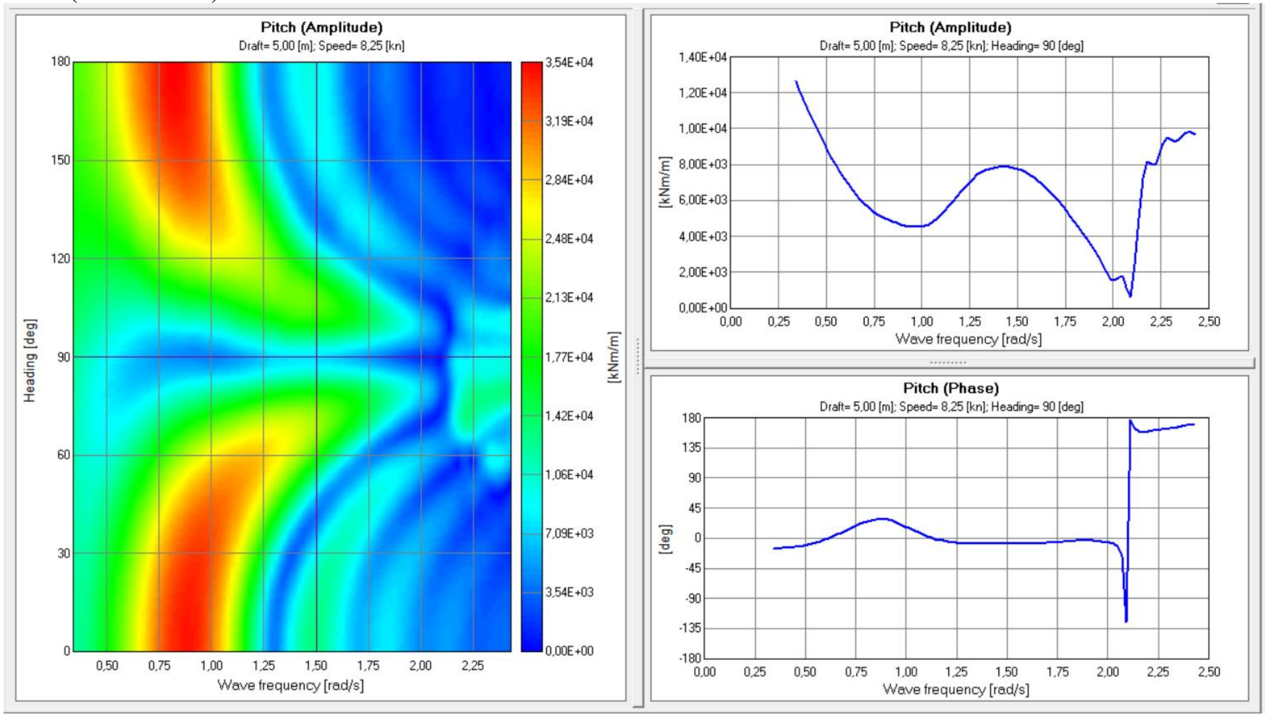


Wave Specter

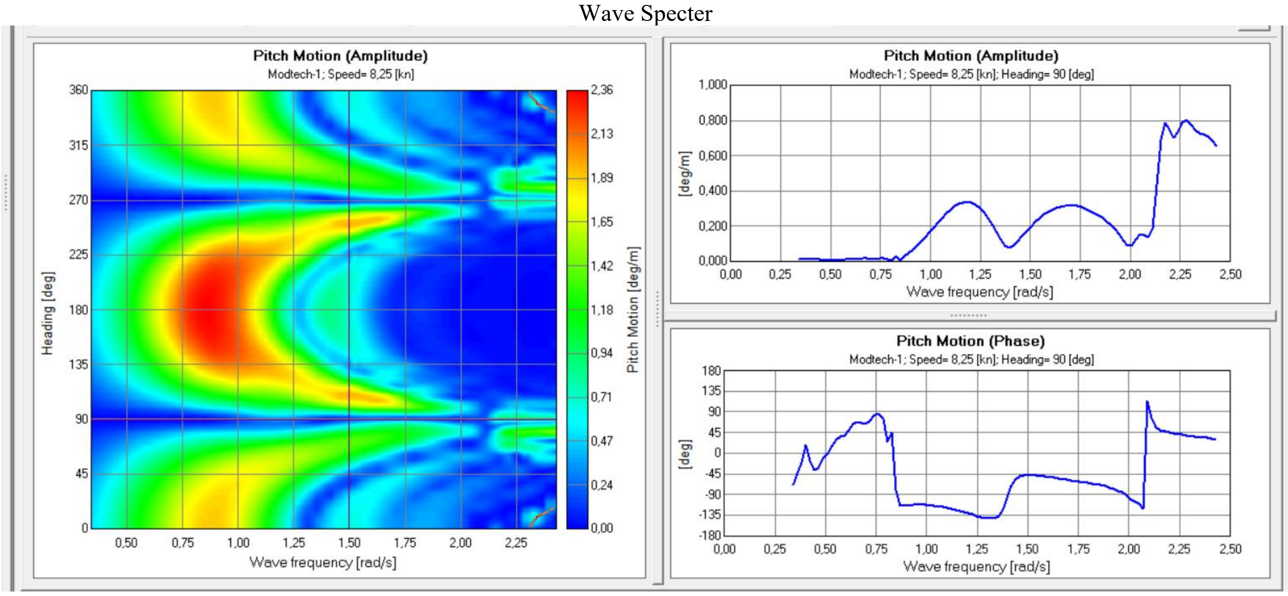


RAO Specter

Table 3. (continuation)



Wave Specter



RAO Specter

The simulation for the modified ship suggests, for an envelope of the ship's travel speeds (2.8 and 8.3 [Kn]) and a heading of 90 [deg], an amplitude of roll motion of 10 [deg] for a wave frequency of 1.75 [rad/s] (Figure 11).

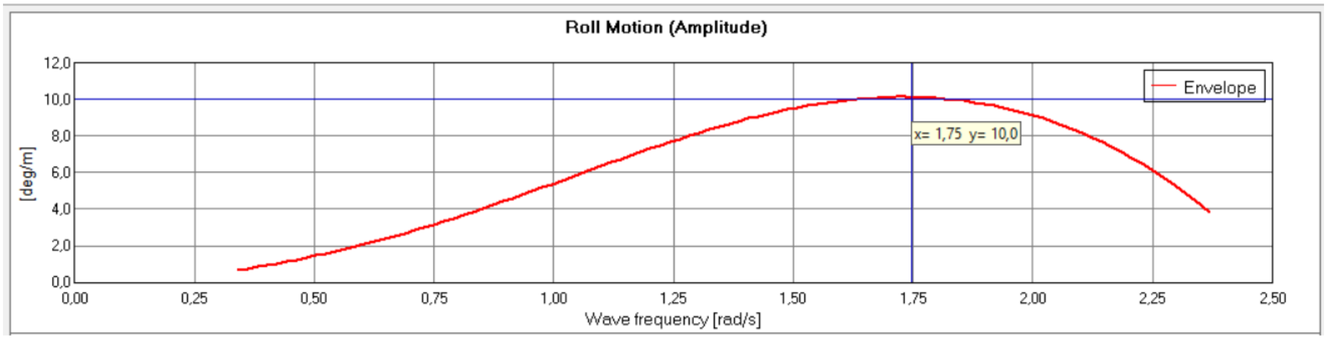


Fig. 11. Roll motion for the modified ship

The simulation for the modified ship suggests, for an envelope of the ship's travel speeds (2.8 and 8.3 [Kn]) and a heading of 90 [deg], also indicates an amplitude of pitch motion of 1.03 [deg] for a wave frequency of 1.30 [rad/s] (Figure 12).

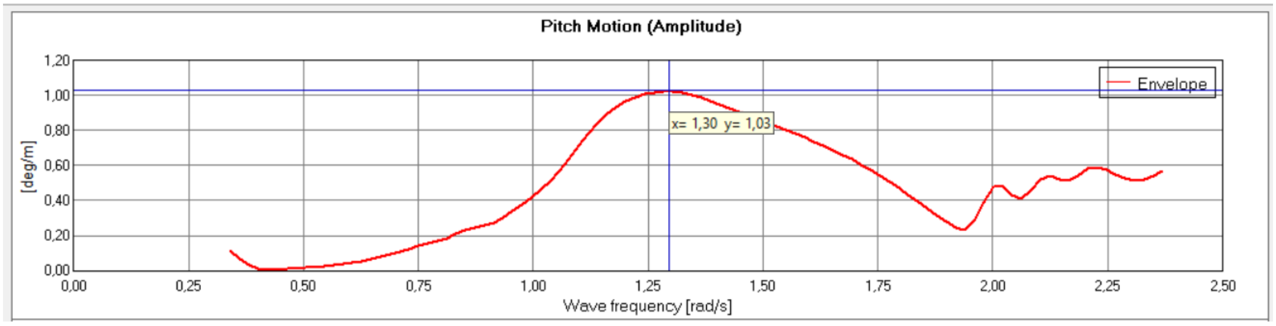
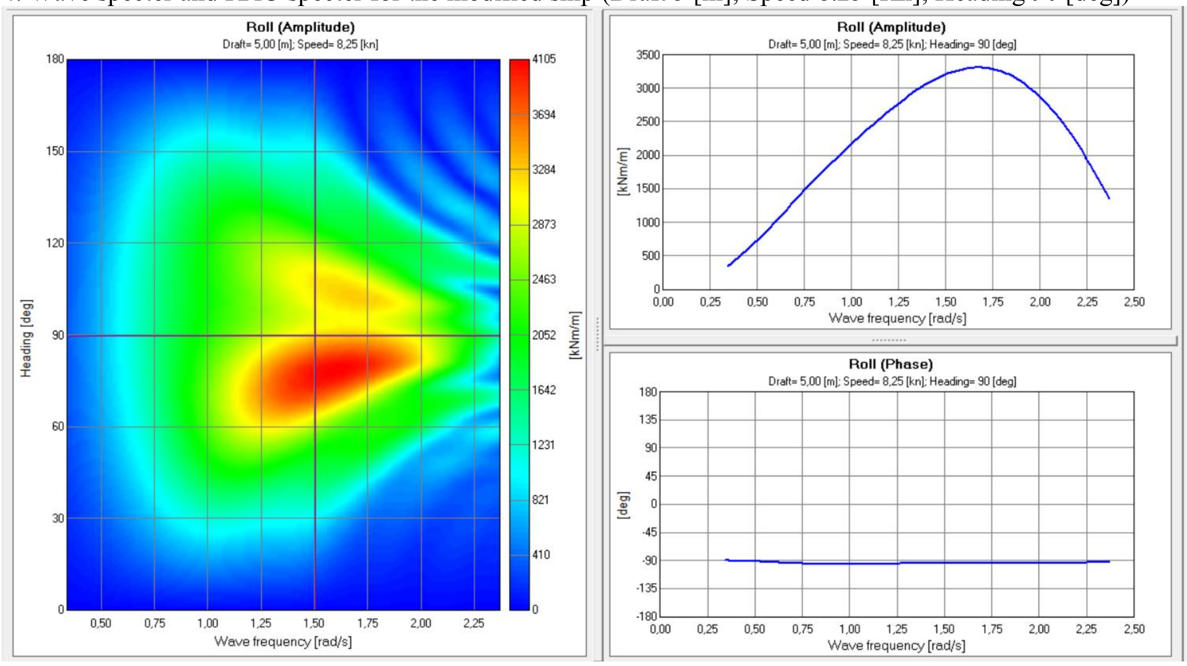


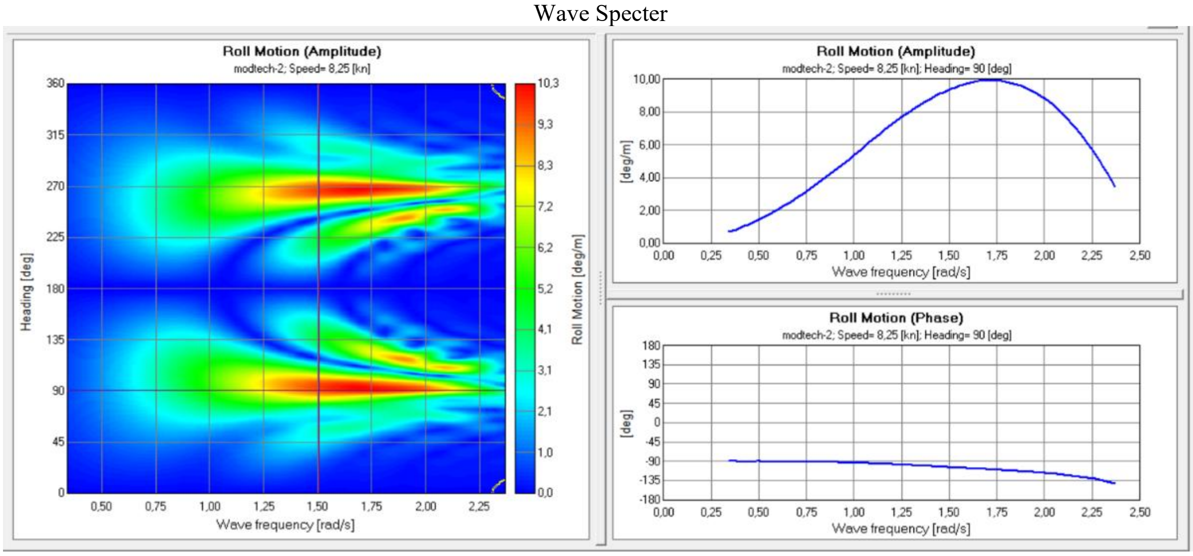
Fig. 12. Pitch motion for the modified ship

Table 4 presents, for the modified ship, some suggestive situations for these two specters – roll and pitch motions were emphasized.

Table 4. Wave specter and RAO specter for the modified ship (Draft 5 [m]; Speed 8.25 [Kn]; Heading 90 [deg])

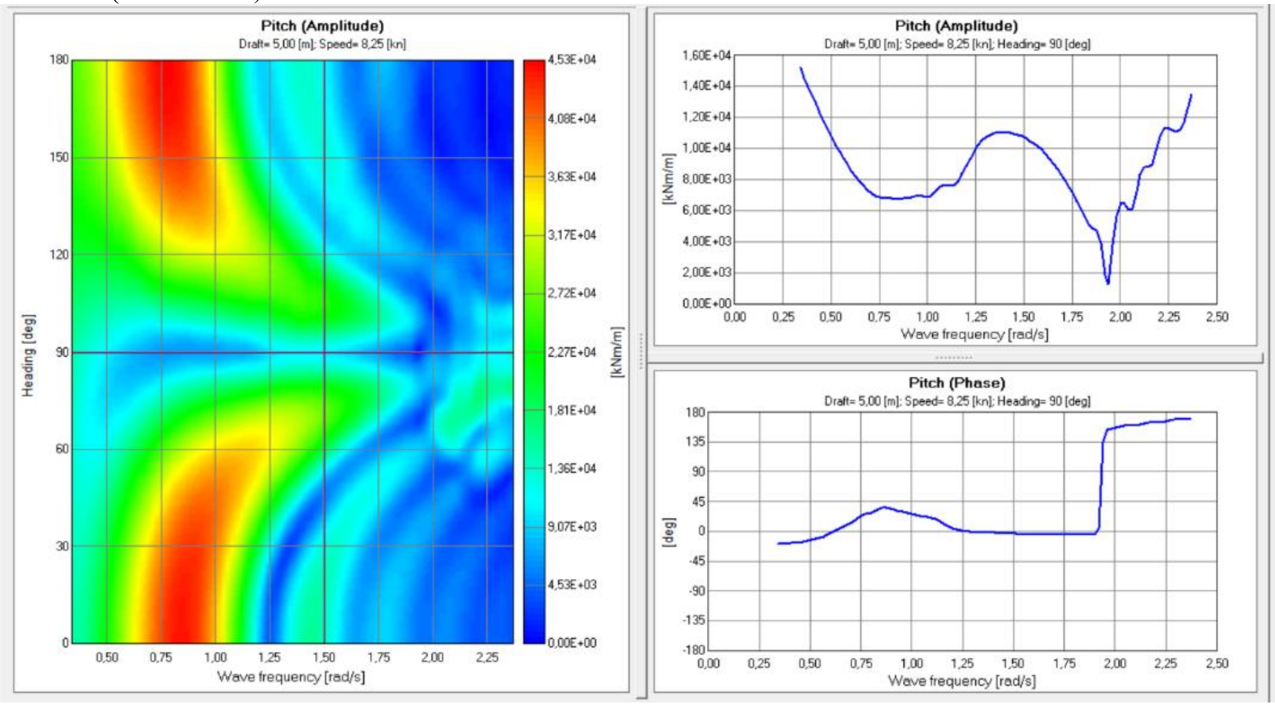


Wave Specter

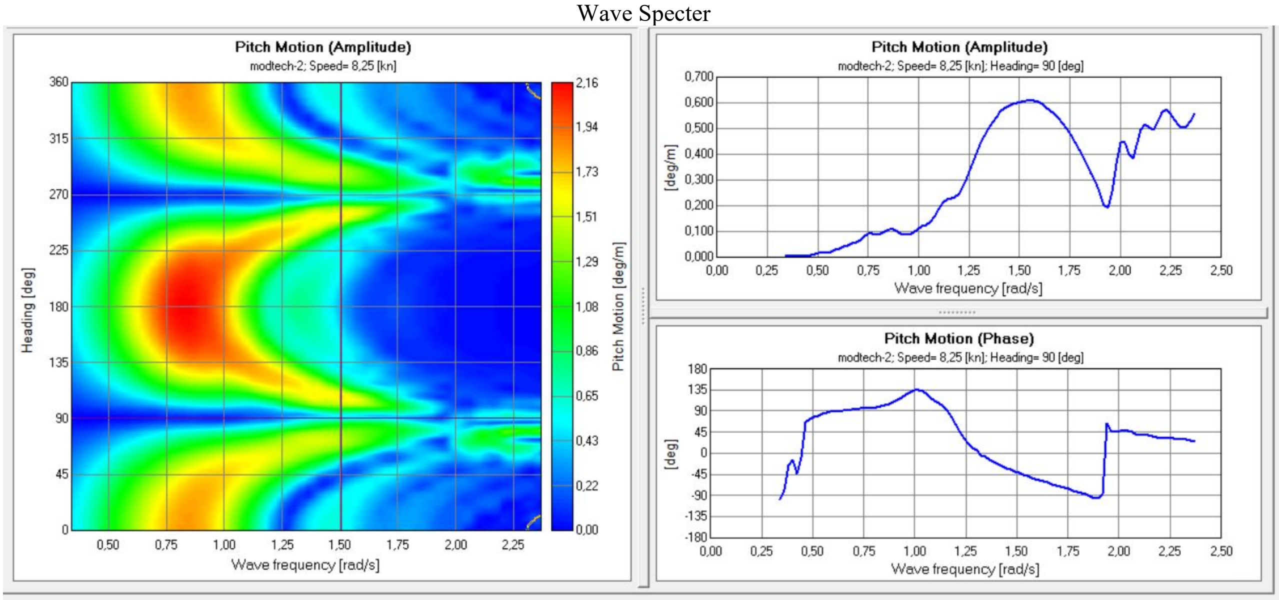


RAO Specter

Table 4. (continuation)



Wave Specter



RAO Specter

4. CONCLUSIONS

For the study carried out, it is proposed to change the length of the ship from 52 [m] to 54 [m], the other dimensions remaining unchanged.
With the help of the available software licenses (AutoShip and Octopus Office) the consequences of this change on nautical qualities were analyzed.
The conclusions are as follows.
The geometry of the ship was easily modified; for the additional 2 [m] in length, the shape of the transverse-vertical section at the stern of the ship was preserved.
The ship's displacement increases from 1966.298 [t] to 2498.927 [t], which means an increase of 27.088%.
The position of the hull center is changed longitudinally by a slight displacement on the stern of the ship, with 0.436 [m] (from $x_B = 24.67$ [m] to $x_B = 24.234$ [m], the measurement being made from the stern of the ship). Also, the center of the hull rises with 0.024 [m] (from $\overline{KB} = 2.886$ [m] to $\overline{KB} = 2.910$ [m], the measurement being made from the baseline).
The geometric center of the water line for the fully loaded ship moves towards the stern with 1.947 [m] (from

$x_{BF} = 22.078$ [m] to $x_F = 20.131$[m], the measurement being made from the stern of the ship).
A slight reduction in transverse stability is also demonstrated by the reduction in the angle for which the maximum value of the stability arm is recorded (angle that corresponds to the moment when the ship enters the water with the deck) from 38.75 [deg] to 30.00 [deg].
As far as dynamic behavior is concerned, it is found that the pitch motion is the one that worsens, the amplitude of the movement increasing from 0.555 [deg] to 1.03 [deg] while the roll motion is improved, the amplitude of motion decreasing from 10.6 [deg] to 10 [deg].
Although the desired construction solution leads to a slight decrease in the stability of the ship, however, this nautical quality remains within the parameters recommended by the classification societies. The dynamic behavior also remains within parameters that do not endanger the ship. Therefore, it can be considered that the proposed constructive solution can be put into practice.

Author contributions: Elisabeta Buzilă: conceptualization; data interpretation; methodology; project administration; software; supervision; validation; review and editing. Mihaela-Greti Manea: data curation (acquisition and analysis); project administration; software; supervision; validation; initial draft writing; review and editing. All authors have read and agreed to the published version of the manuscript.
Funding source: No funding source was involved.
Conflicts of interest: There is no conflict of interest.
Acknowledgements: The authors would like to thank "Mircea cel Batrân" Naval Academy for the use of licenses and to Tulcea Shipyard, Romania, for the access to the specialized documentation.

5. REFERENCES

[1] Ban, D., Blagojevic, B., Barle, J., (2010), *Ship Geometry Description Using Global 2D RBF Interpolation*, Brodogradnja, 61(3), 233-242.
[2] Cepowska, Z., Cepowski, T., (2015), Seakeeping Software for the Analysis of a Ship's Seaworthiness, Scientific Journal of the Maritime University of Sczecin, 42(114), 95-100.
[3] Chalfant, J., Chryssostomidis, C., (2017), *Application of Templates to Early-Stage Ship Design*, IEEE Electric Ship Technologies Symposium (ESTS), 111-117.
[4] Fossen, T., (1994), *Guidance and control of ocean vehicles,* John Wiley & Sons, U.S.A.
[5] Gernez, E., (2019), *Connecting Ship Operation and Architecture in Ship Design Processes*, Journal of Ship Production and Design, 35(1), 88-101.
[6] [Kitamura, M., Hamada, K., Takezawa, A., Uedera, T., (2011), *Shape Optimization System of Bottom Structure of Ship Incorporating Individual Mesh Subdivision and Multi-Point Constraint,* International Journal of Offshore and Polar Engineering, 21(3), 209-215.
[7] Koleva, E., Nikolova, M., (2022), *Development of an Algorithm for Calculating the Stability of a Ship, Applied in OBSS*, International Journal on Information Technologies and Security, 14(3), pp. 36.
[8] Krivoshapko, S.N., (2023), *Tangential Developable and Hydrodynamic Surfaces for Early Sage of Ship Shape Design,* Ships and Offshore Structure, 18(5), 660-668.
[9] Li, C.T., Qi X., Shi, J., Shi, Z.K., Qi, H., (2012), *Ship Lines Modeling Theory of High-Speed Ship Based on the Partial Differential Equations*. Advanced Materials Research, Vol. 602–604, pp. 1827–1830, https://doi.org/10.4028/www.scientific.net/amr.602-604.1827.
[10] Manea, M.G., (translation Cizer, L.D.), (2023), *Naval Architecture. Lecture Notes,* "Mircea cel Bătrân" Naval Academy Publishing House, Naval Academy, pp. 88-92, 98-103, "Naval Transports" Collection, Constanta, Romania.
[11] Papanikolaou, A.D., (2022), *Holistic Approach to Ship Design*, Journal of Marine Science and Engineering, 10(11), 1717, https://doi.org/10.3390/jmse10111717
[12] Pavlovich, I.V., Dmitrievich, D.S., Gennadievich, K.S., (2016), *About Reengineering of Parameters for Modern Fishing Vessels with Cargo Storage in Tanks*, Marine Intellectual Technologies, 2(3), 18-25.
[13] Ramli, R., Sabri, N.M., Zainon, N.A., (2018), *3D Design of a Ship Floating Dry-Dock by Using Simulation Software*, International Conference on Marine and Automotive Technology (ICMAT) - Propelling and Driving Innovative Ideas, Engineering Applications for New Materials and Technologies, 85, 299-311.
[14] Shahzad, M.R., Riaz, Z., (2021), *Development of Tool to Calculate Large Angle Stability and Hydrostatics of a Ship Using MATLAB*, Proceedings of the 18th International Bhurban Conference on Applied Sciences and Technologies (IBCAST), pp. 881-885.
[15] Tampier, G., Salas, M., (2014), *Hydrodynamic Ship Design for Service Conditions,* Ocean Engineering, 75, 23-29.

[16] Qiu, S., Wang, S., Chen X., Qian F., Xiao Y., (2024), *Ship Shape Reconstruction for Three Dimensional Situational Awarness of Smart Ships Based on Neural Radiation Field*, Engineering Applications of Artificial Intelligence, 136, part A, doi: https://doi.org/10.1016/j.engappai.2024.108858
[17] Yang, L.S, Li, AP. et.al, (2016), *XML Based Ship-Block CAD Model Data Exchange for Production Design*, International Conference on Mechanical Engineering and Control Automation (ICMECA), Proceedings Paper, Wuhan, Peoples R China, pp.359-364, Destech Publications, Inc., 439 Duke Street, Lancaster, PA 17602-4967 USA
[18] ***, https://autoship.com/autoship/, accessed January 25, 2025.
[19] ***https://new.abb.com/marine/systems-and-solutions/digital/ABB-Ability-OCTOPUS-Marine-Advisory-System, accessed January 25, 2025.

Received: February 25th, 2025 / Accepted: November 6th, 2025 / Paper available online: December 20th, 2025
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