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OPTIMIZATION OF PLANNING DURING PROCEEDING TO THE ANCHORAGE USING PATH POINTS

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Analysis of the voyage cycle of sea vessels shows that they spend about 20% of the sailing time in confined waters, but it accounts for about 80% of all emergency events.

Turning a ship in the open ocean, when sailing away from navigational hazards, is not difficult, and when using maps 1: 50,000 and smaller, its details are not expressed on the map at all. In confined waters, the water area for maneuvering is commensurate with the geometrical dimensions of the vessel and planning the trajectory of movement, and especially its curvilinear section, becomes of paramount importance.

The most dangerous section of the track, which determines the safety of the vessel's movement, is the curved one. The reasons for this are the speed of the process of moving the vessel when turning, the absence of the planned coordinates of the curved path and the necessary data on the turnability, which are required for their planning.

To eliminate such reasons, it is necessary: to carry out preliminary planning of the coordinates of curved track sections or to automate the process of their calculation, which can be performed while sailing; perform automated control of lateral displacement, relative to the planned coordinates, select a maneuver for divergence and use the maneuver in a timely manner to correct movement; use high-precision methods of determining the position of the vessel, including geodetic ones. Therefore, the purpose of this work is to produce a method for planning the specified coordinates of trajectory by waypoints (WP), based on determining the matrixes of coordinates of trajectory points (TP) of rectilinear and curved track sections through which the ship passes when maneuvering for anchoring. Another aspect of the problem is the lack of the necessary data on the maneuvering properties of braking and turnability of the vessel for all modes of using control actions. Therefore, such tasks are highly relevant.

Based on the contemporary shipbuilding science [1–7], the following navigation support systems can be offered, which produce information in the form sufficient for maritime operations:

1.A navigation device for calculating maneuverable characteristics for the current state of a vessel and its mode of movement and representing data on the characteristics of braking and maneuverability in the form of tables, as given in Table 1.

Table 1. MSC Canaberra *vessel circulation parameters*

The angle of the transfer steering wheel	Parameters	Legend	Laden		In ballast	
			Experimentally estimated, buildings	Experimentally estimated, cables	Experimentally estimated, buildings	Experimentally estimated, cables
5°	Advance	l_1	7,48	6,61	6,18	5,46
	Direct displacement	l_2	7,1	6,27	5,59	4,94
	Tactical diameter	$D_т$	13,62	12,03	10,83	9,56
	Constant diameter	D_y	14,36	14,36	11,26	9,95
	Advance	l_1	5,03	4,44	4,15	3,66

10°	Direct displacement	l_2	4,25	3,75	3,23	2,86
	Tactical diameter	$D_т$	8,34	7,36	6,46	5,70
	Constant diameter	D_y	8,57	7,57	6,47	5,72
15°	Advance	l_1	3,94	3,48	3,25	2,87
	Direct displacement	l_2	2,98	2,63	2,19	1,93
	Tactical diameter	$D_т$	6,00	5,30	4,52	3,99
	Constant diameter	D_y	6,00	5,30	4,35	3,84
20°	Advance	l_1	3,29	2,91	2,71	2,40
	Direct displacement	l_2	3,23	1,97	1,56	1,38
	Tactical diameter	$D_т$	4,60	4,07	3,37	2,97
	Constant diameter	D_y	4,47	3,95	3,08	2,73
25°	Advance	l_1	2,85	2,52	2,35	2,07
	Direct displacement	l_2	1,71	1,51	1,14	1,00
	Tactical diameter	$D_т$	3,65	3,22	2,58	2,28
	Constant diameter	D_y	3,43	3,03	2,22	1,96
30°	Advance	l_1	2,52	2,23	2,08	1,83
	Direct displacement	l_2	1,33	1,18	0,82	0,73
	Tactical diameter	$D_т$	2,95	2,60	2,00	1,77
	Constant diameter	D_y	2,66	2,35	1,58	1,40
35°	Advance	l_1	2,27	2,01	1,87	1,65
	Direct displacement	l_2	1,04	0,92	0,58	0,51
	Tactical diameter	$D_т$	2,40	2,12	1,55	1,37
	Constant diameter	D_y	2,06	1,82	1,09	0,96
Angular speed of involuntary circulation $\pm\omega_0$=0,12						
Rear steering angle $\pm\delta_{po}$=3°						

2.A navigation device for calculating the abscissa of the center of gravity XG [6]. This device makes it possible to automatically determine the coordinates of the ship's center of gravity by the characteristics of the empty ship, which are given in electronic format, based on the volume and location of the cargo. This makes it possible to speed up the process of controlling the ship along the predefined path.

3.A navigation device for the high-precision planning of the pre-defined route of the ship by the trajectory points of the center of gravity, representing the path in the form of the sum of the matrices of the coordinates of rectilinear and curvilinear sections of the path [2]. This device calculates, based on the available coordinates of the waypoints and characteristics of the maneuverability of the vessel, set in the program in advance, the matrices of the sections of the path along which the ship would navigate. The principle of work is based on the calculation of coordinates using a method of segments [9].

4.A system of selecting the number of tugboats for safe maneuvering under extreme conditions [1]. The principle of the system operation is based on determining the number of necessary tugboats by the magnitude of the force of inertia at the allowable speed in the port, which is necessary to ensure the guaranteed safety of maneuvering and to choose a mode of movement. The use of the device to inform the ship's control process during maneuvering when entering a port for mooring could avoid an accident caused by motion control when there is a failure in the main engine operation.

5.A system for assessing the position of a turn pole and its visualization [6,8,9] makes it possible to calculate the TP abscissa based on the values of the vectors of the bow and stern tips of the vessel's waterline. These data come from the Doppler lag and show its position on the indicator. That notifies the shipmaster of the beginning of the turn and the expansion of the width of the maneuverable displacement lane.

6.A system for counting the coordinates of the satellite dish to the center of gravity of the vessel [9] makes it possible to significantly improve the accuracy of the ship's location. This is since the corrections to the position of the antenna are many times higher than the radial rms error in determining the ship's location by modern satellite systems when they operate under a differential mode. The position of the antenna is given in the ship's documents regarding the origin of the coordinates in the form of a distance to the antenna along the X–ιax and Y–ιayaxes, as shown in Fig.1.

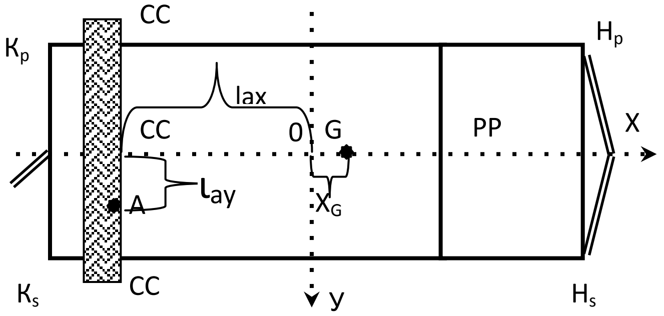

Fig.1. Location of characteristic points on the contour of the waterline:
A–the antenna of a satellite system; XG–the center of gravity abscissa

7.A system of high-precision control over the deviation of the center of gravity of the vessel, from the line of the predefined path, to prevent the ship's grounding, calculates the lateral displacement of the ship's CG relative to the nearest planned trajectory point. It allows for the timely identification of unacceptable sway to take adequate measures to compensate for it [4]. Continuous monitoring of lateral bias automatically makes it possible to assess in a timely manner an unacceptable shift relative to the planned trajectory determined by the high-precision TP matrix.

8.A device for assessing the risk of collision of ships on the course angle of the line of relative movement makes it possible to assess the risk of collision of ships based on a single information parameter – a change in the direction of RML. That makes it possible to increase the speed of decision-making by the shipmaster on the choice of maneuver for divergence.

9.A system for selecting the type of maneuver for divergence based on the nature of change in the line of relative movement during maneuvering [4] makes it possible to determine, based on a catalog, the nature of change in the relative movement based on the situation of convergence and to choose the type of maneuver. A given maneuver must comply with the rules of vessel divergence MPPSS-72/2016.

10.A navigation device for assessing excessive, dangerous, or emergency rapprochement makes it possible to automatically constantly monitor it and, according to the law of the last moment maneuver, to determine the nature of change in the situation. Also, this device selects the type of maneuver for timely collision prevention.

11.A device for estimating the width of the maneuverable displacement [7] makes it possible to constantly determine the width of the maneuverable displacement and requires the introduction of data on the current angular velocity ωf, the boundary value of the angular yaw rate ωpr when following a constant course, and the accuracy in determining the location of the radial root mean square error M0. It takes time to enter and calculate these data. For this reason, better and faster methods for determining maneuverable bias should be used, which make it possible to constantly show the true width of the maneuvering bias, without the need to enter the data required for calculations. In the curvilinear motion shown in Fig.2, the width of the maneuverable displacement of the vessel increases compared to the rectilinear section and is determined by the position of TPs. The limit for determining the nature of the movement is the magnitude of ωpr. To establish the dependences describing the width of the maneuverable displacement.

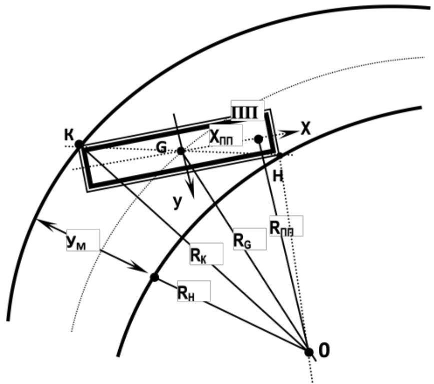

Fig.2.Curvilinear motion scheme at the turn of a ship

Algorithms and computational schemes determine the procedure for increasing the accuracy of planning the route of movement to anchorage area, taking into account the water area for maneuvering, characteristics of braking and turnability and the use of methods for planning the route of movement by trajectory points, including curved sections. To achieve this goal, we will perform the inverse route planning when anchored m / v "MSC Canaberra" on the roadstead of the Chernomorsk Port, as shown in Fig.3.

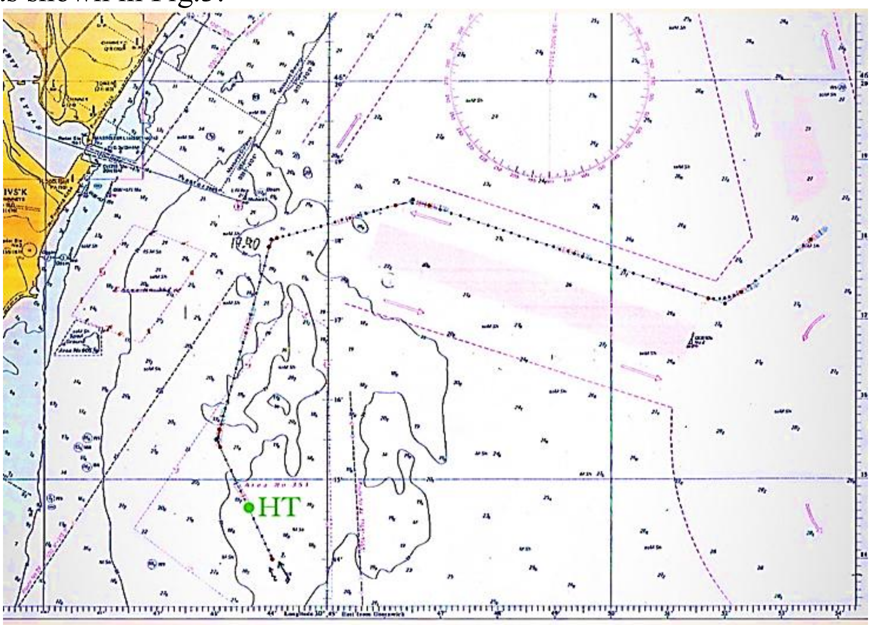

Fig. 3. Planning of the TP maneuvering route when the vessel is proceeding to anchored area No.351 on the roadstead of the port of Chernomorsk

The developed navigation information and analytical complex "Planning the path trajectory using the waypoint matrices" contains modernized methods and techniques for creating a given algorithm for the operation of the ship control system and control over the process of moving along the trajectories, including curved and straight sections of the track when anchored. It automates the anchorage route planning process and controls safe maneuvering, including the use of motion control techniques using dynamic positioning.

REFERENCES

1. Vil’skiy, G. B., Mal’tsev, A. S., Bezdol’niy, V. V., Goncharov, E. I. (2007). Navigatsionnaya bezopasnost’ pri lotsmanskoy provodke sudov. Odessa-Nikolaev: Feniks, 456.
2. Maltsev, S. E. (2019). Navigation device for decision-making support for the automatic planning of vessel movement by trajectory points at entry / exit of the port. Category: marine navigational systems. Science and Education a New Dimension, VII (206) (25), 42–47. doi: https://doi.org/10.31174/send-nt2019-206vii25-106.
3. Sokolenko, V. (2016). The system of precision planning marine ship’s voyage. Proceedings of the National Aviation University, 68 (3). doi: https://doi.org/10.18372/2306-1472.68.109087.
4. Sokolenko, V. I. (2011). Sudovoy plan lotsmanskoy provodki. Sudovozhdenie: Sb. nauchn. Trudov ONMA, 20, 209–220.
5. Sokolenko, V. I. (2012). Planirovanie zadannogo puti dvizheniya v stesnennyh usloviyah traektornymi tochkami i kontrol’ protsessa dvizheniya. Sudovozhdenie: Sb. nauchn. Trudov ONMA, 21, 220–227.
6. Golikov, V. V., Mal’tsev, S. E. (2013). Algoritm opredelniya polozheniya polyusa povorota morskogo sudna. Naukovyi visnyk Kher-sonskoi derzhavnoi morskoi akademiyi, 1, 21–27.
7. Golikov, V. V., Maltsev, C. E. (2015). Analysis of vector of displacement out of way of ship from wind. Naukovyi visnyk Khersonskoi derzhavnoi morskoi akademiyi, 1, 29–35.
8. Mal’tsev, S. E., Tovstokoryy, O. N. (2016). Polyus povorota i ego uchet pri manevrirovanii morskogo sudna. Odessa: NU «OMA», 114.
9. Maltsev, S. (2018). Cognitive assessment system the pivot point position of the vessel with the help of efficient algorithms. Science and Education a New Dimension, VI (171) (19), 37–42. doi: https://doi.org/10.31174/send-nt2018-171vi19-08.