

Fundamentals of training navigators of ships flying foreign flags when entering the inland waterways of the Russian Federation

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Abstract. Navigation on inland waterways, such as rivers, canals, fairways via reservoirs and lakes is performed under conditions of a minimum under the keel clearance, hydrodynamic interaction between the ship's hull and underwater limits of the fairway, and the impact of irregular currents. Piloting a ship difficult navigational conditions requires the navigator to monitor continuously the ship's motion, assess quickly the situation and develop optimal decision for ship handling, have sufficient navigational experience and a large amount of practical knowledge. To achieve a high level of qualification, the training of navigators is carried out in several ways at once - general and particular pilotage, organization of navigation safety and the theoretical foundations of ship handling. Lack of theoretical or practical knowledge can lead to wrong assessment of navigation situation and therefore be considered as factor limiting passage of vessel and navigational safety. The article contains analysis of inland waterways navigation particulars as basis of training for navigators of ships flying foreign flags when entering the inland waterways of the Russian Federation to reduce influence of limiting factors and support the navigational safety.

1 Introduction. General characteristics of pilotage methods via inland waterways of the Russian Federation

The Russian Federation has long inland waterways (IWW), which have significant differences in navigation, hydrographic and hydrometeorological navigation conditions. The IWW of the Russian Federation includes rivers, navigable canals, reservoirs, lakes, for each of the listed waterways it is possible to distinguish the characteristic navigation conditions that require navigators to use various methods of the vessel pilotage, as well as using a combination of such methods.

The complexity of the task of ship piloting via IWW is associated with the need to take into account the entire spectrum of forces acting on the ship and the action of which is variable and completely determined by the conditions of navigation [1-4].

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In difficult navigation conditions, typical for the IWW, the pilotage of the vessel is carried out on the basis of the knowledge of a local sailing directions, while several methods of pilotage can be distinguished, which have distinctive features:

- pilotage method based on visual assessment of the ship's motion using qualitative patterns for assessing the parameters of the ship's motion when piloting via IWW, taking into account external influences;
- mathematical modelling method based on the use of mathematical models of the ship's controlled motion, which allow modeling and quantitatively taking into account the influence of both external factors and the actual ship's controllability, in relation to the circumstances and conditions of navigation;
- calculation-instrumental method based on a preliminary navigational calculation in relation to particular waterway, which allows obtaining calculated data, being combined into a navigation scheme, will allow the navigator to conduct a comparative assessment of the actual parameters of the vessel motion with the calculated ones and perform reasonable corrective actions.

Comparative analysis of the application of all three ship piloting methods for the conditions of IWW includes two stages [5, 6]:

- assessment of safe depth;
- establishment of the necessary width of the maneuvering lane, which ensures the safe motion of a single ship under the most unfavorable combination of hydrometeorological factors.

The application of all methods for training of a navigator to work on the IWW implies the presence of a large number of different professional competencies, the preparation for which takes a long time. Significant for science and practice is the issue of distinguishing from the entire spectrum of navigational competencies, those unique possession of which is especially important for ensuring navigational safety when piloting a vessel through new navigational areas.

2 Navigation directions of the Russian Federation IWW

Piloting the vessel through the waterways buoyed according to the lateral navigational system of IWW is based on knowledge of navigation conditions, which are characterized by the dimensions of the fairway, hydrological and meteorological regimes, and the presence of hydraulic structures. The dimensions of the fairways determine the size and draft of the vessels that can navigate a given waterway, and the requirements for their propulsive and maneuvering qualities. The hydrological and meteorological regimes determine the speed of currents, fluctuations in water levels, the conditions of ice formation, ice drift and freeze-up, the formation of various kinds of superficial obstacles in the channel, the frequency and duration of fogs, snowfall, wind, etc. The conditions for navigation on rivers do not remain constant even for one river both in terms of its length and periods of navigation. A distinctive feature of the ship motion through rivers in their natural state is, first of all, that it occurs in the conditions of a current and a constrained fairway, which has relatively small widths, depths and turn radius, thereby causing the presence of limiting areas, which include: crossings, sharp bends in the channel, bifurcation of the channel, etc., as well as the locations of various engineering and hydraulic structures.

Sailing directions of the IWW include verbal descriptions of the features of the currents influence depending on the period of navigation, as well as materials for calculating their numerical values, necessary for navigators, contained in the navigation and hydrographic essay, as well as characteristics of local navigation conditions, information from a special sailing directions [7].

Knowledge about particulars of the action of basic currents, resulted in their uneven distribution depending on fundamental factors, such as depth, turn radius, can be used if it is necessary get more speed both when proceeding downstream and upstream. The ship's intended track should be chosen within the area, with maximum current velocities, on the way downstream and within area with lower current velocities when proceeding upstream, located closer to the banks often having shallower depths.

The uniqueness and variability of navigation conditions, therefore, requires the navigator to assess continuously the navigational safety, taking into account both the ratio between the main ship dimensions and the dimensions of the fairway, the ship's maneuvering characteristics and hydrometeorological factors such as wind, current, waves, the water level, and, consequently, the change in depth, which is especially important when navigating via shallows.

Taking into account the specific conditions of navigation on the inland waterways, each of these indicators significantly affects the safety of navigation and must be taken into account for the training of navigators [8,9].

3 IWW buoyage system

IWW aids to navigation (AtoN) system is established by national standard 26600-98. Understanding the mainstream of the floating aids to navigation system, as well as the principles of placing floating AtoN, is closely related to the considered features of river currents [6,7].

When piloting a ship on the IWW visual assessment of the vessel's position is possible both on the basis of orientation relative to floating and fixed marks of navigation equipment, which allows to assess the area of dangerous depths, is carried out by dividing the water area covered by the chart into areas of dangerous and safe depths. Fast and accurate orientation when piloting a vessel is achieved through the use of a system of navigation equipment for inland waterways, consisting of land and floating marks, each of which has its own purpose and is installed in accordance with a specially developed and approved scheme of navigation equipment, i.e. determination of the position of the vessel relative to the boundaries of the channel, as well as the correctness of the course in relation to the directions of the channel.

An example of scheme of arrangement of floating navigation marks on the section of the river Sheksna, in vicinity of Torovo, where the fairway is divided, is shown in Fig.1.

Navigational difficulty of this section of the river is caused by sharp turn with significant heading changes, possible hydrodynamic interaction of the hull with the shallow port side limit of the fairway, the variable effect of aerodynamic force caused by gusty winds blowing from the Rybinsk reservoir. Frequently placed port- and starboard-hand buoys according to the lateral navigational system of IWW help the navigator to assess external factors of influence and maneuverability of own ship as well.

When proceeding in shallow waters, a significant wind effect and variable in direction and speed, as well as a curvilinear current, it is advisable to focus on reducing the variability of the vessel's motion parameters under the influence of external factors than on accurately keeping the vessel on the trajectory.

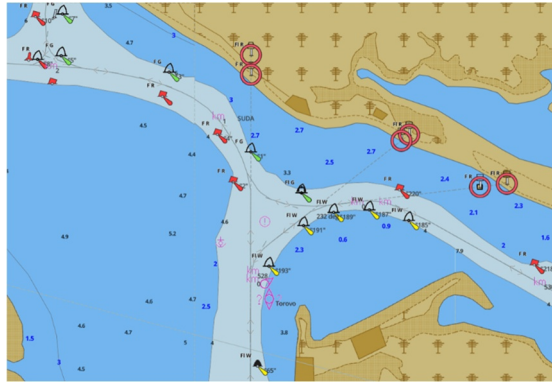


Fig. 1. IWW fragment of the electronic navigation chart of the river Sheksna in the vicinity of Torovo.

Floating marks of navigation equipment allow the navigator to visually assess the position of the navigation channel, determine its characteristics, and also allow solving operational tasks, important decision-making on maneuver the ship:

- determine the position and direction of the main fairway, which is important for rivers with a branched channel;
- plotted closer or farther from the dangerous contours allow the navigator to control the safe distance without taking measurements;
- allow navigators to pay attention to separately lying navigational hazards;
- the frequency of installation of floating marks of navigational equipment makes it possible to obtain information about the complexity of navigation conditions, i.e. the action of currents, a sharp change in depth;
- help to determine the optimal directions for following the fairway, as well as its the dimensions;
- allow navigator to visually mark the start and end points of the turn.

4 Practical acquisition of navigational information when piloting a vessel via IWW

Knowledge of ship handling should rather be considered not as a theoretical justification for performing maneuvers, but as practical skills to perform such maneuvers, for example, to proceeding at minimum speed, ship handling during anchoring and mooring operations, to maneuver when passing locks. When maneuvering in narrows, it becomes important not so much theoretical as practical knowledge, which implies the ability of the navigator to act in connection with the circumstances and conditions of a particular case. Controlling ship's motion in difficult navigation conditions is not just a mental skill it requires navigator constantly to work out in practice what they have learned in theory. With the limiting influence of the dimensions of the passage, in addition to the ability to use the means of controlling the vessel, the navigator is required to have reliable knowledge of navigation instructions, which allow to assess continuously the position of the vessel and correct her motion.

When piloting the vessel via the IWW, the electronic chart display and information systems (ECDIS) showed their effectiveness for orienting the navigator and assessing the parameters of the vessel's motion in relation to ensuring navigational safety [10-12].

The position of the vessel on the fairway can be described by the following parameters: distance from the center of mass of the vessel from the axis of the fairway and drift angle. The basis of piloting a vessel in narrows, typical for the IWW, is the accuracy of space estimation and time calculations. In order to improve the safety of navigation and ensure the possibility of quick adoption of correct and reasonable decisions, the ECDIS provides the navigator with information characterizing all aspects of the navigation process in a clear and easily interpretable way.

Orientation using ECDIS was carried out by visual comparison of the space between the sides of the own ship symbol (OSS), displayed on the chart scale and dangerous isobaths, as well as the minimum number of visually displayed kinematic parameters – the heading line and the speed over the ground (SOG) vector with divisions of the time scale.

Setting the ENC scale allows to set optimally the display of the own ship symbol and the surrounding area. Alerts that are triggered automatically when the chart is displayed on a larger scale than the original i.e. when overscaling or less than the original is called underscaling can be used as auxiliary information.

The use of vector electronic charts has the following advantages, which allow changing both the volume and the accuracy of the observed space, which, together with the display of the kinematic parameters of the ship's motion, increases the accuracy of the ship's piloting:

- display of chart in a user-friendly scale;
- full screen display of any fragment of the chart;
- simultaneous view all areas of the current chart and any other one;
- quick obtain information on any navigation aid displayed on the chart;
- regulation of the load of the chart by turning off or adding to display any groups

of objects.

It will be important to control the ship's motion near the limits of the fairway or certain navigational hazards, since the effect of hydrodynamic forces and moments on ship will change both in nature and in intensity depending on its position relative to the shoal. Displaying the symbol of own ship in the form of a contour on the chart scale in combination with kinematic parameters allows to take into account the hydrodynamic interaction between the ship's hull and the edges of the channel when following the axis of the channel, or near the limits of the channel, due to deviation.

When ship is proceeding through the fairway having significant amount of water on one side and lack of water from the other, or in case of considerable congestion of the fairway when cross-section value of the fairway approaches to middle frame square. In this case vessel motion is affected by the venturi effect, that makes stern or stem comes closer to the shoal is scoured and suction will become stronger as a result. An example is the Moscow River, a fragment of an electronic navigation chart of one of the sections of which is shown in Fig. 2.

In the general case, when following the axis of the section under consideration, one should expect hydrodynamic interaction, since its axis is towards the port fairway limit. The use of ECDIS makes it possible to adjust vessel position and motion relative to width and direction of the fairway refine the heading angles of the apparent wind and to correct the ship's motion depending on the wind directions, which can either increase the ship's turn or hard it over.

Despite the complexity and variability of navigation conditions, control over the position and kinematic parameters of the vessel's motion, performed using ECDIS, showed an increase in the quantitative accounting of the influence of wind and current on the vessel. Conventional signs displayed on the chart, in particular signs of floating navigation equipment, do not affect the perception of the navigational situation around the vessel by the navigator when orienting according to ECDIS, since the navigator observes the motion of the vessel directly relative to dangerous isobaths. However, depending on the functional

features of the ECDIS displayed by the ENC, it is possible to achieve a greater improvement in the quality of orientation, taking into account the impact of a combination of external factors, as well as their separate accounting without the use of conventional signs, for example, by reducing the interval between isobaths to the minimum values and using a four-color palette for depth display.

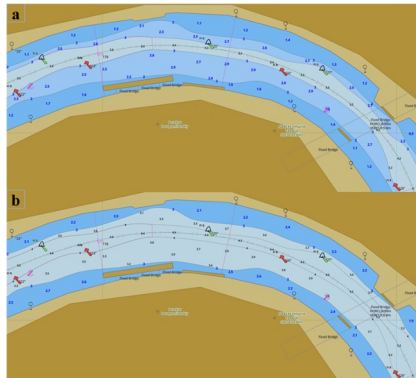


Fig. 2. IWW fragment of the electronic navigation chart of the river Moscow near the Dorogomilovsky shallows: a) with low water level; b) with high water level.

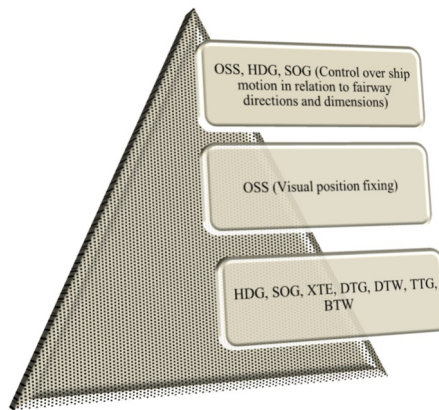


Fig. 3. Hierarchy of navigation information in relation to ship piloting via IWW.

The figure shows the hierarchy of the amount of information generated by the ECDIS and the navigation information used in relation to the control the passage of vessel via IWW.

In the event of the occurrence of circumstances that complicate navigation and may endanger the ship, it is necessary to take all possible advance measures for the implementation of navigation required by the situation. However, when following the IWW, especially in areas difficult for navigation, the navigation situation around the vessel can change in an unpredictable way, which excludes the possibility of taking into account

all possible navigation situations in advance. Therefore, there is a need to solve a whole range of problems related to the training of navigators, assessing their competence, and his ability to make decisions on ship handling in various navigation conditions.

Regardless of bridge navigational equipment especially ECDIS used for piloting the vessel, use floating aids to navigation in combination with local knowledge helps navigator to solve the following important tasks:

- Relation between vessel steering ability and turning radius of the fairway;

- Continuous visual positioning of the vessel;

- Evaluation of the impact of irregular currents;

- Possibility of visual heading correction.

Main direction of training foreign navigators to work on the IWW of the Russian Federation is the study of general and special sailing directions which, in turn, allows to get proper understanding of following important points:

- the hydrological regime of rivers, lakes and reservoirs;

- assess the possible impact of various hydrometeorological factors on the motion of ships;

- establish the relationship between the aids to navigational equipment and navigational conditions within a basin or waterway;

- the characteristics of the motion of ships in river and reservoir navigation conditions;

- the main methods of orientation on waterways.

5 Conclusions

The current stage of development of means and systems of navigation is characterized by an increasing contradiction between the high requirements for the safety of navigation, on the one hand, and a fairly high level of navigational accidents on IWW, on the other hand. This largely determines both the need for further improvement of navigational aids and systems, and the training of navigators to work in conditions of dangerous navigational situations, a comprehensive and holistic description of the set of events leading to dangerous navigational situations, as well as an analysis of the consequences of the development of dangerous navigational situations.

Despite significant differences in the navigation conditions via IWW, the identification of ship control features based on numerical calculations for various combinations of external influences makes it possible to identify general theoretical patterns, which can be taken into account due to the standardization of navigation equipment, especially floating equipment, and thereby reduce the information load on navigator.

The above provisions of this article are used in the course of additional professional education designed to prepare foreign navigators for the passage of Russian inland waterways. The course was developed by Admiral Makarov SUMIS team as part of the "Future Potential of Inland Waterways" project, INFUTURE, KS1006, fulfilled in 2018-2022 and financed within the Cross-Border Cooperation Program by Russian Federation, Republic of Finland and European Union.

This article has shown that the main direction of training foreign navigators to work on the IWW of the Russian Federation is the study of general and special sailing directions: which, in turn, makes it possible to get proper understanding of the hydrological regime of rivers, lakes and reservoirs, assess the expected impact of various hydrometeorological factors on the motion of ships, establish the relationship between the floating aids to navigation and navigational conditions within a basin or waterway, the characteristics of the motion of ships in river and reservoir navigation conditions, the main methods of orientation on waterways.

It was clearly shown that the basis for ensuring the navigational safety of navigation of ships on IWW is the knowledge of general and special sailing directions. The use of ECDIS set to the navigational features of a particular area of the IWW allows navigators to receive operational information not only about the parameters of the vessel's motion, but also about the external factors that cause this motion.

This year marks the 10th anniversary of the Admiral Makarov SUMIS membership in the association EDINNA. Years fly in productive cooperation. The authors of the article thank the Board of the EDINNA association, our colleagues from different countries, and the secretariat of the EINC2022 for the invitation to participate in the General Assembly and the conference. By sharing our professional knowledge and skills in the inland navigation studies and training, we together show the advantages of this mode of transport and its future prospects for the economic prosperity of our people and countries.

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