Research on accuracy increase of the process of avoidance of the vessels collision in congested waters

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Abstract  Rapid development of computer aids and modern navigation equipment for the merchant vessels gives possibility for navigators to solve complex problems for collision avoidance of the vessels during the sailing in congested waters.

When vessel sailing in congested waters the decision making about vessels maneuver based on navigators’ experience only may cause the problem for navigation and increase risk of collision. Installation of the shore navigation equipment and Vessel Traffic Services (VTS) plays important role for increasing the navigational safety. But despite this the risk of collision still exists.

The task of the research of the process of the vessels collision avoidance remains relevant and accident rate level documents it.

Moreover the levels of vessels axiomatization cannot exclude the human factor error in navigation.

Research and development of the method for accuracy increase of the parameters of the ship's maneuver for collision avoidance is very relevant.

Key words: Maritime Transport, Safety of Navigation, Collision Avoidance, Risk Assessment, Ship's Maneuvering

1. Work's Relevancy

Rapid development of computer aids and modern navigation equipment for the merchant vessels gives possibility for navigators to solve complex problems for collision avoidance of the vessels during the sailing in congested waters.

![Figure 1 Collision of the vessels in the congested waters](image)

With recent performance improvement of observation devices and introduction of new information systems, VTS is expected to play larger role in supporting the officers onboard. According to IMO Resolution A.857 (20), Vessel Traffic Service is implemented to improve the safety and efficiency of vessel traffic and to protect
the environment. VTS are shore-side systems that evolved as a response to the increased complexity of shipping and the need to prevent congestion by maintaining a safe traffic flow. The services are basically of two types; one is predominantly found in coastal areas or straits that are characterized by congested shipping lanes, while the other type is used to control the traffic movement in and out of ports. VTS are designed to provide support to vessels by services that range from the provision of simple information messages, such as position of traffic in the vicinity, to extensive management of the traffic flow. In general, vessels entering a VTS covered area report to the authorities by radio, and are tracked by the VTS control centre. The vessels keep watch on a specific frequency for navigational or other warnings, while they may be contacted directly by the VTS operator if there is risk of an incident or, in areas where traffic flow is regulated, to be given advice on when to proceed.

However, an increase in the volume of available information demands higher skills in critical situation awareness and operational decision-making in complex situations. Assessment of collision risks and evasive maneuvers still to a degree depends on human individuals. Practical solutions so far include training and acquiring experience, although long-term experience does not guarantee that the right decisions will be reached. The task of the research of the process of collision avoidance of the vessels remains relevant and accident rate level documents it. Moreover the level of vessels axiomatization cannot exclude the human factor error in navigation. Research and development of the method for accuracy increase of the parameters of the ship’s maneuver for collision avoidance is very relevant.

2. Purposes and tasks of the research
The purpose of the research is to increase the safety of the ships maneuvering for collision avoidance by development the methods for accuracy increase of the ship’s maneuvering parameters in congested waters.

2.1 Research goals
Research object is the ships maneuvering process. Research subject is accuracy of determination the parameters of the ships maneuver for collision avoidance.

For achievement of the research goals the following tasks were set:

- analysis of the existing and development of new methods of the assessment of the risk of collision;
- development of the method and decision algorithm for safe actions of the collision avoidance maneuver;
- development of the algorithm of calculation the range of the vessels safety courses during the collision avoidance maneuver;
- development by the various ways of the algorithm of determining an error in calculation of the parameters of the vessels closest point of approach (CPA).

Figure 2 The functional scheme of the safety collision avoidance of the vessels
2.2 Scientific novelty of the obtained results
1 - 90 ≤ α(t); 2 - α_{min} ≤ α(t) ≤ 90; 3 - 0 < α(t) < α_{min};
4 - -α_{min} < α(t) ≤ 0; 5 - α(t) ≤ -α_{min}; 6 - α(t) ≤ 90.

Figure 5 The collision situation dependences by α(t)
Minimum value of the $\alpha(t)$:
$$\alpha^{(i)} = \arcsin \left( \frac{D_{\text{rel}}}{D_{\text{AB}}} \right)$$

where $D_{\text{AB}}^{(i)}$ - distance between the vessels in time “i”:
$$D_{\text{AB}}^{(i)} = \sqrt{\left( X_A^{(i)} - X_B^{(i)} \right)^2 + \left( Y_A^{(i)} - Y_B^{(i)} \right)^2}$$

The algorithm of vessel’s action for collision avoidance is developed. This algorithm considers three types of maneuvering for each vessel and its dynamic. The following results with scientific novelty were obtained:

- the method of the collision risk assessment by heading angle to relative movement line (RML) was developed;
- the method of vessels collision avoidance during the movement on curvilinear trajectory was developed;
- the conceptual model for the ensuring safety collision avoidance of the vessels was developed;
- the selection method of the vessel safety action in time of collision avoidance with unlimited number of the vessels was developed;
- algorithms of the assessment the calculation error in the CPA parameters were improved.

![Figure 6 Block diagram of the collision risk assessment by heading angle to relative movement line (RML)](image-url)
3. Research methods and practical value

For the theoretical part of the research the following methods were used: the method of the operational research, the method of information theory in navigational tasks, mathematical modeling, the theory of random processes with elements of probability theory and mathematics statistics, methods of assessment of the navigational safety level, differential and integral calculus.

Experimental part of the research included the full scale investigation on the merchant vessels and computer simulation. Experiment data was processed by mathematics statistics methods.

Research results can be used in navigation to increase the navigational safety and reduce the accidents number by fuller information support for the vessels collision avoidance. Obtained results form base for improvement of the functionality shore based navigational aids and for fuller information support of the navigation in congested waters. Research results concerning automatic calculation of the range of safety courses and selection safety action of the vessels can find application in automatic radar plotting aid (ARPA). Obtained results also may be useful for researches and investigation connected with design of ports, canals and vessels traffic schemes.

References