AUTOMATION OF THE EXIT TO THE ELLIPSE OF THE GIVEN RISK

Mamenko P. P., Zinchenko S. M., Nosov P. S., Kyrychenko K. V., Mateichuk V. M.
(pavlo.mamenko@gmail.com; srz56@ukr.net; kvklecturer@gmail.com;
mateichykv@gmail.com; pason@ukr.net)
Kherson State Maritime Academy (Ukraine)

One of the most important stages of the automatic divergence of courts in the field of risks is considered - entering the ellipse of a given risk. Movement along the ellipse of the given risk allows you to minimize the distance of divergence and fuel consumption, preserving the given risk of collision for all participants of the operation.

Formulation of the task. Existing methods of preventing the collision of vessels presuppose the use of linear methods of dispersion by course, speed or combined. The divergence method, consisting in the optimization of the divergence trajectory, with a given risk of collision for all participants in the operation, appears to be more effective. The implementation of this method consists in the organization of sliding the ellipse of the given risk of one's own ship along the ellipse of the given risk of the target. The most important stage of such a divergence is the stage of entering the ellipse of the given target risk, which is considered in detail in this study [1-10].

List of solved problems: to develop a method of automatic exit of one's own vessel to the ellipse of the given risk of the target, for optimal divergence; to develop the algorithmic support of the automatic control module of the exit to the ellipse of the given risk, to develop the software for the simulator of the on-board controller of the simulation simulation stand, to carry out simulation modeling of the processes of exiting to the ellipse of the given risk of the target.

The essence of the research. An important element of the divergence maneuver is entering the ellipse of a given risk, for optimal divergence of vessels, and exiting the ellipse of a given risk, to continue moving along the given route. In fig. 1 shows the calculation scheme for determining the coordinates of the point A of the beginning of the circulation and the coordinates of the point B of the end of the circulation, when the own ship enters the ellipse of the given target risk

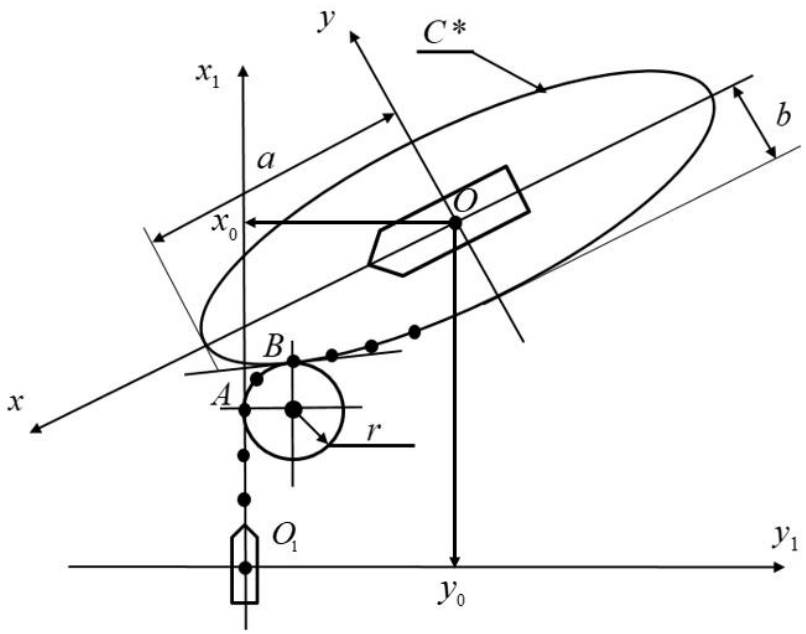

Figure 1. Calculation scheme for entering the given risk ellipse

The coordinates of point B are defined as the coordinates of the point of contact of the circulation circle with a radius r to the ellipse of the given risk of the target with poles a,b. The quation of the circulation circle r in the coordinate system $O_1X_1Y_1$ associated with one's own vessel has the form

$$(x_1 - x_A)^2 + (y_1 - r)^2 = r^2 \quad (1)$$

The equation of the ellipse in the coordinate system OXY associated with the target has the form

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \quad (2)$$

The coordinate system OXY is shifted by $\mathbf{x}_0 = (x_0, y_0)$ and rotated relative to the coordinate system $O_1X_1Y_1$ by an angle φ , which is determined by the difference in the courses of the own ship and the target. The transition from system $O_1X_1Y_1$ to system OXY is determined by the system of equations (3)

$$\begin{aligned} x &= (x_1 - x_0)\cos\varphi + (y_1 - y_0)\sin\varphi \\ y &= -(x_1 - x_0)\sin\varphi + (y_1 - y_0)\cos\varphi \end{aligned} \quad (3)$$

Taking (3) into account, the equations of the ellipse (2) in the coordinate system $O_1X_1Y_1$ will have the form

$$\begin{cases} \dfrac{(x_1 - x_0)^2}{a_1^2} + \dfrac{(y_1 - y_0)^2}{b_1^2} + \dfrac{(x_1 - x_0)(y_1 - y_0)}{c_1^2} = 1 \\ a_1^2 = \dfrac{a^2 b^2}{(b^2 \cos^2\varphi + a^2 \sin^2\varphi)} \\ b_1^2 = \dfrac{a^2 b^2}{(b^2 \sin^2\varphi + a^2 \cos^2\varphi)} \\ c_1^2 = \dfrac{a^2 b^2}{(b^2 \sin 2\varphi - a^2 \sin 2\varphi)} \end{cases} \quad (4)$$

The coordinates x_0, y_0 of system (4) are determined by formulas

$$\begin{aligned} x_0 &= D\cos P \\ y_0 &= D\sin P \end{aligned} \quad (5)$$

according to the results of measuring the bearing *P* and distance *D* of the radar. The coordinates of the end of the circulation and the beginning of the movement along the ellipse of the given risk $x_1(B), y_1(B)$ are found by the compatible solution of the nonlinear equations (1), (4), (5) at each cycle of the on-board computer. The coordinate of the start of circulation is located as

$$\begin{cases} x_1(A) = x_1(B) - r \\ y_1(A) = y_1(B) \end{cases} \quad (6)$$

The coordinates of the starting point from the ellipse of the given target risk are determined in a similar way.

Experiments. Operability and efficiency of the developed method and algorithms in the problem of divergence from targets with the criterion of minimum risk was tested on Imitation Modeling Stand, created by authors on the basis of the Navi Trainer 5000 of the simulator laboratory of the Kherson State Maritime Academy.

Conclusion. A method of automatic exit of one's own ship to the ellipse of a given target risk has been developed, for optimal separation; the algorithmic support of the module for automatic control of the exit to the given risk ellipse was developed; the software of the simulator of the on-

board controller of the simulation simulation stand was developed, the simulation simulation of the processes of entering the ellipse of the given risk of the target was carried out.

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