Safety Operation of Marine moving Objects

Golikov Vladimir[1], *Maltsev Anatoliy*[2]

The aim of present research is working out a conception of provision for assured safe manoeuvring of vessel at the expense of perfection of attendant activity of navigator and improvement of agreement of movement factors with hard and variable limitations, aimed at making algorithms appraising navigation situations, decision making on correction of set algorithm of control.

The decision of problems put forward the explanation of notions. So, maneuvering strategy requires set of possible actions for the achievement of the assigned task is understood as available recourses of security information, which operator is able to perform, it forms hypotheses to solve the problem. The tactics of manoeuvring foresees the decomposition of each hypotheses, that allows to follow from initial problem to elementary and make their typification.

For grounding of the ways of achievement of the above aims the analysis of the accidents on the basis of the material available in the Harbour Master office inspections of Ukraine and legal expert examinations was effected. As a result the ranging of human errors connected with the operator's actions was made [7]. As it follows from the Ukrainian ship accident rate during 1978 – 2002 the navigational accidents in the Ukrainian territorial waters make 79 % which twice exceeds the World average statistic data.

The performed analysis of the accident rate and the errors in the actions of the human operator (HO) shows that they are mostly the results of the insufficient agreement between the process character peculiarities and those at the actions of HO, as an element of the whole system as well as the factors of the movement with variable and constant limitations.

For the quantitative appraisal of the manoeuvring safety multi-factor criterion of agreement of psychophysiological characteristics of operator's activity with the process of manoeuvring movement factors is to be introduced. It includes in the least five movement factors and four characteristics of the operator's activity.

The movement factors are the speed the course, the manoeuvring trajectory configuration and position check up.

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[1] Proffesor, ONMA Vice Rector

[2] Proffesor, Head of the Shiphandling Department of ONMA

From the point of view of operator's activity the errors arise in the process of receiving visual information, as it requires processing. This stage of malfunction is characterized by the loss of orientation, its share makes 31,8 % of all 173 cases analyzed. For their elimination it is necessary to process the information and present it to the operator in the form of procedure recommendations, which would be accepted as requiring one single action. If outer influences and certain variable limitations change, the operator is required to process the entering declarative information on the check up of the control process parameters for the correction of the planed trajectory. This stage results in the errors in the manoeuvring process control the share of it constitutes 23.1 % .

The delays in the operator's intellectual activity influence the speed and reliability of decision making and the check up of its realization. This stage leads to the errors in observing the rules of navigation, and their share is as big as 17.5 % of all the cases of accidents.

The safety of manoeuvring in the above cases was not provided due to the absence of the necessary data of the ship's manoeuvring characteristics as an object of the control and the corresponding data of the navigation technical aids current state for the monitoring the movement in the congested conditions of navigation grounding of ships in 46.8 % of 173 analyzed cases gives a sound evidence to that.

The insufficiency of information provision of the navigation process both inside the ship and from outside, the absence of the ways and methods of monitoring by the shore – based Aids to Navigation did not allow to prevent grounding of ships (47%) and contacts to coast line and clearing marks (17 %).

The information provision of the current parameters of the movement and the situation of the ship is also insufficient the absence of the methodology of the ship control preliminary planning, supporting systems for the decision making and the algorithms of the operator's actions in the manoeuvring control, which didn't allow to prevent collisions in 15 %, grounding in 47 % and contact accidents in 17 %.

This analysis made it possible to rank the operator's arrows in accordance with his psychophysiological characteristics: in 47 % of all cases the cause was the fault of the analyzer in 21 % as a result of malfunction while storing and processing the information; in 18 % faults in decision making and in 14 % motor mistakes caused by the low capacity to the work of the operator.

For the evaluation of the influence level of every particular characteristic on the process of the movement let us introduce the coefficients of ranking analyzers

$K_{\text{ржа}} = 0,47$, malfunction in storing and processing the information $K_{\text{ржп}} = 0,21$, the speed of the intellectual functions fulfillment $K_{\text{ржи}} = 0,18$ and the result of motor's faults $K_{\text{ржм}} = 0,14$.

The planned values of the movement factors are to be taken as the starting point, and the maximum assured results is achieved by the maximum possible approximation of the planned values of the parameters to the optimal values. Thus, the efficiency of the

manoeuvring is determined by the predicted characteristics of the movement process and the ability of the operator to fulfill the prepared plan.

For the evaluation of the coordination let us introduce the three factors of movement and the operator's characteristics – local, generalized local and global ones.

Local Criteria of Coordination - show the degree of coordination of every characteristic of the operator with corresponding factors of movement. Their general number is 20. The denotation of the coefficients is given in Table 1.

In case of agreement of one factor of movement with one characteristic of the operator it acquires the value 0.2, if it is absent it equals 0..

Generalized Local Criteria of Coordination – informational analysis ($K_{ан}$), memory and thinking ($K_{пам}$), the speed and reliability of intellectual functions ($K_{фун}$) and anthropometry ($K_{ант}$) characterizes the degree of the agreement of every characteristic feature of the operator with all the factors of the movement. Everyone acquires the values [0;1]. In case of the agreement of one factor of movement with the corresponding feature $K_{ан}, K_{пам}, K_{фун}, K_{ант} = 0{,}2$, two factors – 0.4, three – 0.6, four – 0.8 in case of full coincidence 1.

Table 1. *Local coefficient of coordination*

Traffic factors	Analizators	Memory	Intellectual functions	Anthropometry
Speed	Кса	Ксп	Кси	Ксм
Course	Кка	Ккп	Кки	Ккм
Manoeuvre starting moment	Кма	Кмп	Кми	Кмм
Trajectory	Ктра	Ктрп	Ктри	Ктрм
Situation	Кпа	Кпп	Кпи	Кпм

Global Criterion of Coordination ($K_{сог} \in [0;1 \text{ отн.ед}]$) characterizes the degree of agreement of all the characteristics of the operator's activity with all, the factors of the ship movement, represented as separate coefficients.

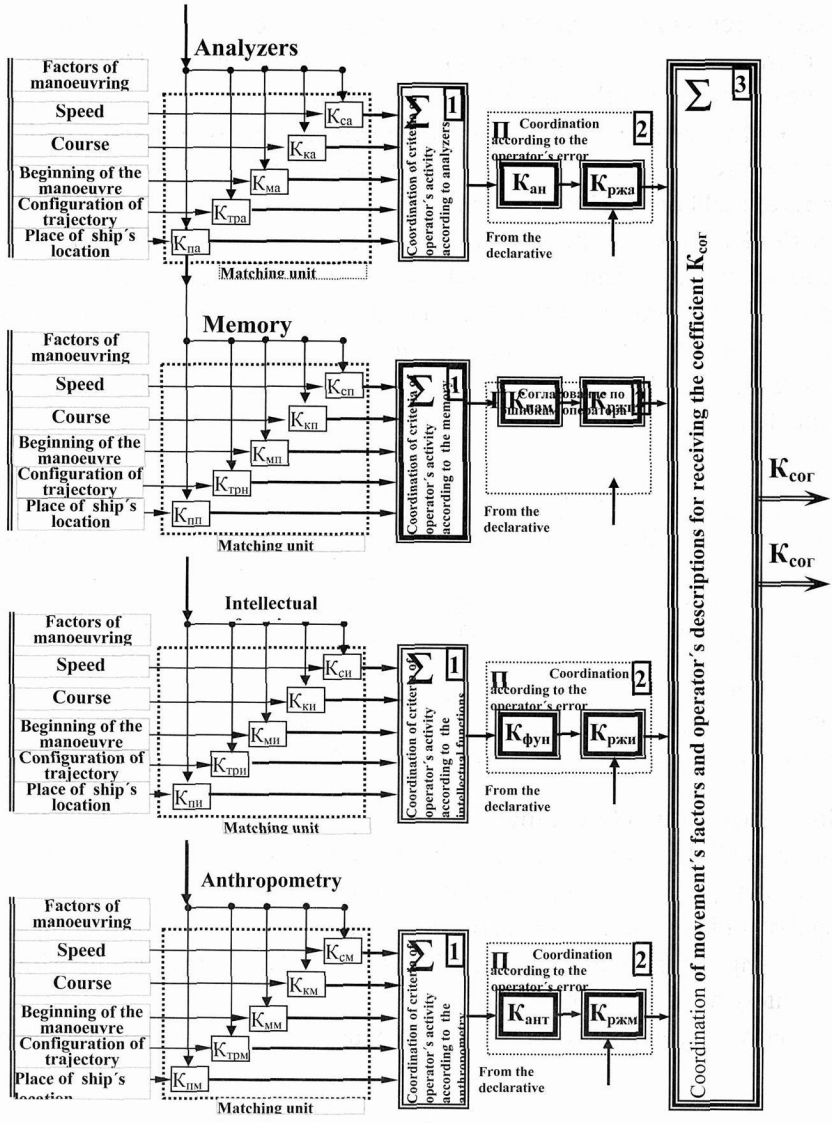
If global and generalized local criteria are equal to one it means that the agreement of all the components of the manoeuvring is ensured and the precompositions for the ensured safety have taken shape.

The analytical dependence for the determination of $K_{сог}$ will look in the following way:

$$K_{сог} = \sum_{i=1}^{4} \left(K_{ржі} \cdot \sum_{j=1}^{5} K_{локij} \right) \qquad (1)$$

where i - the number of operator's characteristics ($i \in [1;4]$); j - the number of traffic factors $j \in [1;5]$; $K_{рж}$ - coefficient of operator's errors ranking; $K_{лок}$ - local coefficient of coordination (table.1).

The structural scheme of algorithm of determination of coefficient by formula (1) and is shown in the picture.1.



Picture 1 – Structural scheme of algorithm of coordination coefficient. Marking of blocs: 1 –coordination according to the local criteria; 2 –coordination taking into account operators´ errors; 3 – global coordination

Considered necessary and sufficient conditions allow to proceed to substantiation of process of assured safety of manoeuvring.

When the preliminary plan is made up, one may proceed to the fulfillment of the following manoeuvring stage–operation of transition process. For its realization it is necessary: to carry out the sea operation on going out from the port; to customize hydrameteorological factors and adjust the corrections, which had been taken according to the predicted data; to bring in to the work control unit of course (manual or automatic), navigational facilities which determine the shipś position , which evaluate the navigation situation and which determine the moment of appearance of variable limitations to the movement of the ship. When one defines the location and finds some deviations it is necessary to specify reasons, which stimulated removal and correct the course, without changing the preliminary plan, in order that the ship go out exactly to the following travel point.

When variable limitations appear, one should find out, if there is a danger of collision, and correspondingly, and the necessity to change the parameters of movement. If it exists, then one should correct the preliminary plan by means of removal of the following one or several travel points in the direction of cargoś delivery (transference lines between ports).After this the course or speed is changed to provide with the divergence and with the realization of the given algorithm of operation.

Out of the accident rates analysis and the study of the manoeuvring process, the existing practice of protection of the safety of traffic has a lot of shortcomings : there is no information about manoeuvring properties ; the conception of the prediction and the planning of the given algorithm of the system of operation, and the method of sea operation planning are generally absent; the systematized conception of the movement correction by the variable limitations is also absent ; there is not enough information about current parameters of the movement and their correspondence to the planned ones ; there is no supporting system of decisions ́assumption.

Thus, the safety of the manoeuvring operation is intended to assure due to the rise of level of awareness and to the speed system of processing information with the following elaboration of the algorithm of operatorś activity by means of : the structuring of the tactical and efficient tasks, the elaboration of the algorithm of intellectual actions of the operator while the planning or operation of the shipś movement; the elaboration of the algorithms and programmes which predict the safe speed in different conditions of navigation ; planning of the sea operation by means of the method of inversion; the creation of the supporting system of the assumption of decisions which concern the manoeuvring ; the creation of the algorithms of the current control of the divergence and correction means of the initial trajectory; the creation of the algorithms of the current control of the position, including the curvilinear motion, and the visualization of the current situation of the divergence with the ships which manoeuvre dangerously.

Bloc-scheme of the algorithm of the functioning of the system in the mode «preparation» is given in the picture.

In the mode «Transition» the work of the system of the manoeuvring safety, is presented by the procedure, in which the following operations are performed:

- B_1 –collection, processing and reflection of information about strict limitation for the beginning of the movement;
- B_2 - collection, processing and reflection of information about parameters of external influences and visibility conditions;
- F_3 - determination of the necessity of including the correction data in the compass course for the compensation of the external influences ;
- B_4 - determination of the safe speed in accordance with the conditions of navigation taking into consideration manoeuvring characteristics;
- B_5 - determination of the manoeuvring characteristics for the current situation in the organs of control and their assessment;
- B_6 - determination of the current meaning of the dynamic characteristics and the corrective coefficients to account for the shallow water;
- F_7 - comparison of the dynamic characteristics on deep water and current correlation H/T and assessment of the necessity of correction of characteristics of the current regime of movement;
- B_8 - determination of the actual meaning of the shipś course $KK_{тек}$;
- F_9 - comparison of $KK_{тек}$ and $KK_{зад}$ and making of the command to the rudder transfer for bringing the ship to the established course (operation along the inner outline);
- B_{10} - determination of the current position of the ship;
- F_{11} - comparison of the current position of the ship with the given one, assessment of the divergence from the line of the planned way and clearing up the cause;
- B_{12} - determination of new meaning of the corrections due to the external influences, $KK_{зад}$ and modification of the given algorithm of operation ;
- B_{13} -the establishment of the variable limitations;
- B_{14} -determination of the time of the modification of regime, the selection of kind of manoeuvre in the catalogue of situation;
- F_{15} - comparison $KK_{тек}$ and $KK_{зад}$ and formulation of the command to the helm for bringing the vessel to specified course or the assignment of a new value of the speed;
- B_{16} - determination of the beginning moment of return and the new value of course to the following travel point;
- B_{17} - determination of the angle of turning the rudder, a moment of starting and finishing of the turn, holding of the turning and the new meaning of $KK_{зад}$ taking into account the angle of windage and sea current;
- B_{18} - determination of the position data of the starting point of a rerunning of the rudder;

- F_{19} - transfer of the rudder to the specified angle after arriving at the point of the turning and keeping it taking into account the characteristics of holding of the turning;
- K_{20} - end of the lead cycle of the vessel trough the given section between the previous and the subsequent points, with an opportunity of reiteration of the cycle on a following section of the way and transition to operator B_2.

In the operational form of LSA operator's activity of a navigator during the transition by the sea is represented in a following way:

$$H\, B_1\, B_2\, F_3^{2\uparrow 4\downarrow}\, B_4\, B_5\, B_6\, F_7^{8\uparrow 6\downarrow}\, B_8\, F_9^{10\uparrow 8\downarrow}\, B_{10}\, F_{11}^{12\uparrow 8\downarrow}\, B_{12}\, B_{13}\, B_{14} \times \\ \times F_{15}^{12\uparrow 16\downarrow}\, B_{16}\, B_{17}\, B_{18}\, F_{19}^{2(20)\uparrow 16\downarrow}\, K_{20} \qquad (3)$$

and the block diagram of the algorithm of system activity of maneuvering in this mode is indicated in figure .3.

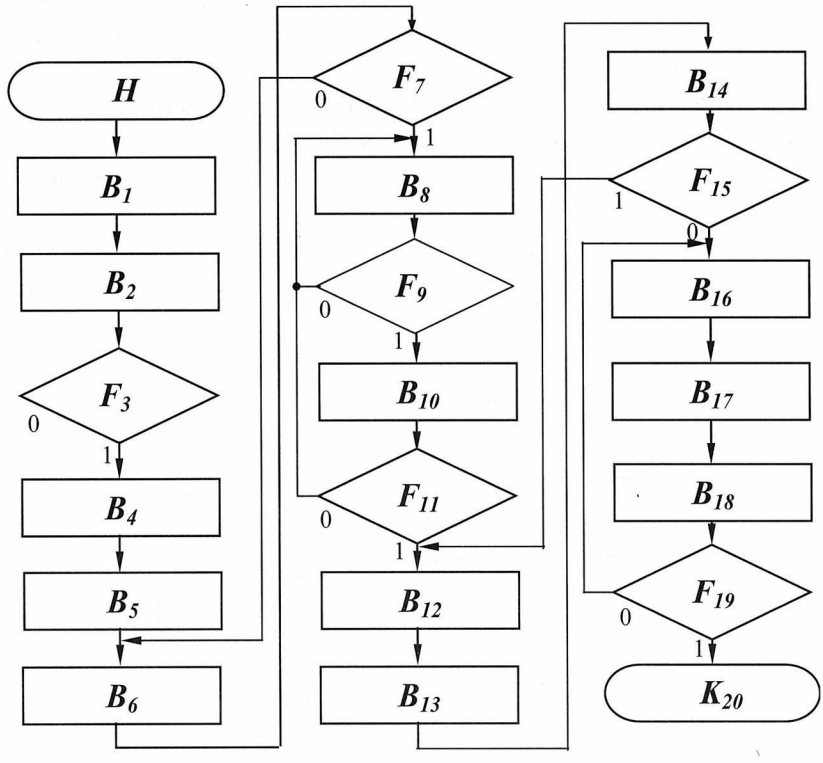


Fig.3. the block diagram of algorithm of operation functioning system of maneuvering «transition» in regime.

Operational peculiarities of assured safety system of maneuvering during the performance of marine operations consist in the fact that a vessel purposefully changes parameters of its movement. During the performance of marine operations, owing to the given limitation on a trajectory of movement, three classes of operational problems are distinguished: with the loose port end with unfixed time: with the fixed ends: with loose port or starboard ends.

Usually a starting point of maneuvering while entering a port is the initial point which coincides with last travel point, and while going out from a port maneuvering begins with the jammed point, and terminates in the initial travel point.

During the anchoring the jammed point is the point of going down of an anchor, and initial point is last travel point. During the mooring on the move the finish point of the maneuver moves evenly and rectilinearly.

During the performance of marine operations the procedure of system functioning is presented by following operators:

- Нм – beginning of structural logic algorithm of functioning the system;
- $B_{м1}$ – collection, processing and displaying of the information about strict limitation for starting flow;
- $B_{м2}$ - collection, processing and displaying of the information about parameters of external influences and conditions of visibility;
- $B_{м3}$ - choice of manner of arriving to the finishing point of the maneuvering, course and speed;
- $F_{м4}$ - determination of the necessity of corrections in the magnitude of compass course for compensation of external influence and the necessity of tugboats for safe maneuvering;

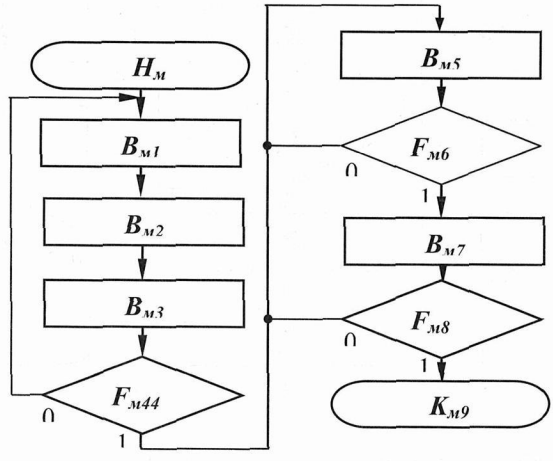


Fig.4. Block diagram of the operation algorithm of maneuvering during the marine operations

- $B_{м5}$ - graphic construction and analytic calculation of coordinates of the initial point of starting /finishing maneuver;
- $F_{м6}$ - check up of the transition points coincidence and initial one of starting of the maneuver, if there is any discrepancy subsequent plan of flow on the transition is corrected;
- $B_{м7}$ - determination of corrections for changing the course and/or speed for coming to initial travel point or position for starting the maneuver;
- $F_{м8}$ - check up of coincidence of points and transfer of the system to «transition» mode or its correction by changing either the starting travel point or by changing the course in the first travel point.
- $K_{м9}$ - the end of the cycle activity on the given segment of flow.

In the operational form of LSA activity of a navigator during the performance of marine operations can be written down in a following way

$$H_м B_{м1} B_{м2} B_{м3} F_{м4}^{5\uparrow 1\downarrow} B_{м5} F_{м6}^{7\uparrow 5\downarrow} B_{м7} F_{м8}^{9\uparrow 5\downarrow} K_{м9},$$

and the block diagram of the algorithm of system activity of maneuvering is shown in the figure.4.

Conclusions and Propositions

1. Existing concepts in navigation are based on physicalistic approach, using basically kinematic and kinetic laws of flow and the cybernetic approach, using laws of the theory of automatic.
2. Suggested conception of control assured safety of maneuvers is based on system approach. The information processing function and the operation of a vessel function in it are automated to the maximum, and operator's activity of a navigator is exposed to algorithmization in processes of a choice and decision-making.
3. Automation is required the studying of processes of maneuvering, researching a quality of a vessel, as an object of the control, and external RFI and informational influences on the process of the control, and structure development of the control system, a decision-making support system and fast-acting algorithms of intellectual activity of the operator.
4. In the process of algorithmization of the navigator's activity on the base of the criteria of coordination his psychophysiological characteristics and factors of movement three modes of operative management were marked –preparation, transition and marine operations which were undergone preliminary research on the level of logical operations and determinations of block diagrams.

5. The following research is rational to direct to creating the structure of the operational system of maneuvers for different conditions of navigation, class of solving problems and create the conditions for providing assured safety of navigation, including the upgrading the pilotage as an effective means of navigation safety.

Reference:

1. Зеленин М.П. Эргономика на морском транспорте. – Одесса. : Банто, 1999. – 382 с.
2. Антонов А.В. Системный анализ.-М. : Высшая школа, 2004. -454 с.
3. Наука,1978.-245 с.
4. Герасимов И.Г. Структура научного исследования.-М.:Мысль,1985.-217 с.
5. Колесников Л.А. Основы теории системного подхода. -Киев. : Наукова думка,1988.-171 с.
6. Кейхилл Р.А. Столкновения судов и их причины. – М.: Транспорт, 1987. – 248 с.
7. Юдович А.Б. Предотвращение навигационных аварий морских судов.2 –е изд., доп. – М.: Транспорт, 1988. – 224 с.
8. Романов Г.С. Анализ аварийности в районе БДЛК и ХМК за период 1999-2002 годы.//Судовождение: Сб.научных трудов ОНМА.-Вып.6.-Одесса :Феникс,2003.-С.108-114.
9. Мальцев А.С. Система управления движением судна// Судовождение: Сб. научн. трудов./ ОГМА. –Вып. 3.- Одесса.: Латстар, 2001.-С.106-121
10. Мальцев А.С, Романов Г.С., Гончаров Е.И., Вильский Г.Б. Подготовка лоцманов к управлению маневрами судна .//Судовождение :Сб. научн. трудов/ ОНМА,. Вып.8. –Одесса: Феникс,2004. –С. 63-76.