The ways of enhancing the safety of navigation.

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ABSTRACT

The shift of priorities in fitting out the bridge is the most characteristic feature of modern navigation. Ship's position determination by means of satellite systems is prevailing nowadays. The current developments negatively influenced the navigator. He stopped using the classical methods of navigation. Besides some problems have arisen finding no solutions by now. The following problems are worthy of special attention: pilotage, sharing the responsibility between the master and the pilot; manoeuvring characteristics of the vessel and taking them into account when planning a manoeuvre.

Pilotage diminishes the risk of navigating accidents. It is evident that the desirable solution of the problem is the division of responsibilities between the pilot and master, and giving their relations a legislative form of a pilotage contract where the obligations and responsibilities of both parties are to be clearly defined. The conflict between the master and the pilot arise on the ground of absence of the clear division of their roles, functions in the ship advancement control system.

The existing nowadays situation in the issue of ship's manoeuvring characteristic data provision does not comply with the modern requirements to the safety of navigation warrants. The necessity of the manoeuvre preliminary planning is declared theoretically to be essential but it is impossible to put it into effect due to the absence of the necessary data. The way of solving the problems is the creation of the full structural scheme of a ship's movement control system and working out the methods of manoeuvre planning taking into account the ship's characteristics.

1. The information for the captain about manoeuvring properties of the vessel.

The principal peculiarity of modern condition of the science of handling the vessel is the aspiratic to automate process of handling the initial data, display of the situation, acceptance of the decision and fulfilment of manoeuvring without intervention of the navigator. However before automating any process of handling, it is necessary to learn to carry it out manually, and then to have it formalised. Fast change of conditions and unpredictability of influence of the external factors result in the necessity of taking decisions on ship s handling in circumstances of uncertainty and shortage of time and that is always risky. Production-economic risk and high price of an eventual error result in the fact that the handling of a vessel in difficult conditions is carried out by the captain of a vessel. The safety of navigation thus is determined by master s skill of handling the vessel. Such skill can be obtained only by repeated fulfilment of operations of handling vessels on simulators and on the bridge during her exploitation. The attempt of a rigid regulation of actions of the navigator while handling the vessel by the edition of manuals and instructions does not give positive effect, as the majority of documents order, what it is necessary to carry out, but do not enjoin how to make it. Three ways of formation of steady skill of accomplishment of elements navigator's works are shown on fig1.

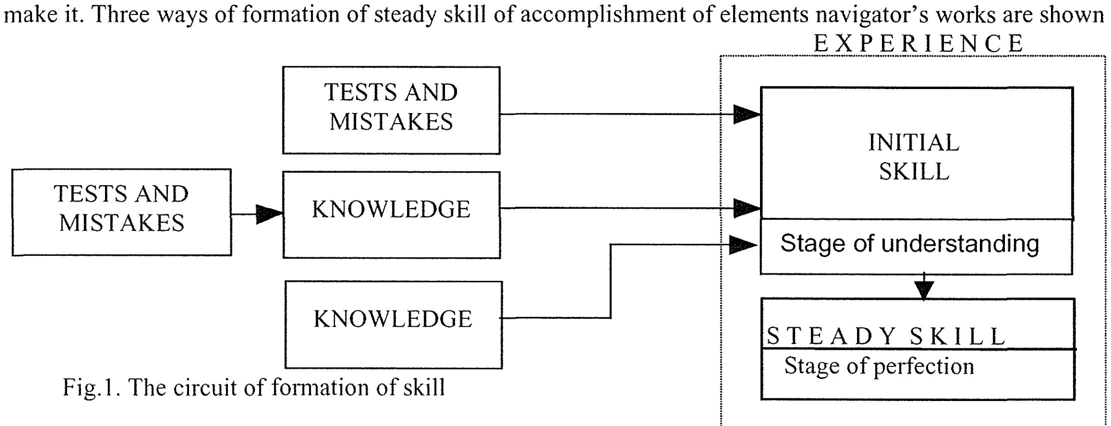

Fig.1. The circuit of formation of skill

The analysis of navigation incidents shows, that they have taken place in most cases not because of malfun c-tion of means of navigation and handling or late detection of danger, but owing to the readiness of navigators to accept the decisions on steering control adequate to a developing situation. It occurs the reason, that the navigator has not enough sufficient experience. The personal know-how of the navigators on handling the vessel consists of the sum of skills of fulfilment of definite elements of navigator s work (turns, navigation in fairways and in constrained waters, mooring in port and sea etc.). It is acquired in result of long work at sea, mainly by a method of tests and errors. However there is a number of kinds of activity of the navigator at handling a vessel, when he is compelled to work without the right for an error.

The absence of proper skill handling a vessel is especially displayed with navigators who are allowed to work independently on the bridge as the chief mate, captain or pilot for the first time. Therefore for development of proper skill proficiency we use a system of training and work on the bridge at sea with an extra master, which requires significant expenses. It is more preferable to form the initial skill on the simulator.

For the description of a vessel as of the object of handling manoeuvring characteristics are used. They can be divided into two groups: stopability and turnability (fig.2). In conformity with the offered classification the stopping characteristics are: dispersal, substopping, passive braking and active braking. The characteristics of circulation include: constant time of delay of turn $T(\delta)$; course keeping ability, criterion Q; a zone of instability $\pm\varpi_o$,$\pm\delta_{po}$; of meeting the turn, time $t_m(\delta)$,angle $\Theta_m(\delta)$;advance $l_1(\delta)$; transfer $l_2(\delta)$;a tactical diameter of circulation $D_t(\delta)$; a final diameter of circulation $D_f(\delta)$. About most of them navigators have no information (according to IMO recommendations 20% only).

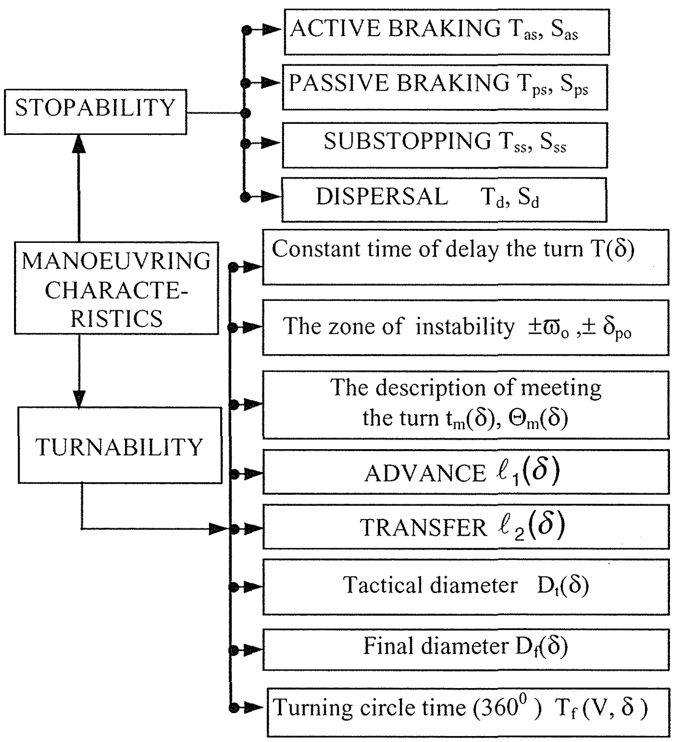

Fig.2. Classification of the ship s manoeuvring characteristics

For uniform interpretation of each of the specified characteristics we shall give their definition. Dispersal -process of increase of speed from a smaller step to greater. Substopping- process of reduction of speed from a greater step to smaller. Passive braking - process of reduction of speed of a movement at the stopped main engine on account of water resistance. Active braking is process of reduction of movement speed at the expense of a thrust of the propeller, working astern.

In order to consider each element of circ u-lation, it is necessary to consider the turn of a vessel in detail. With the beginning of turning a rudder at a movement of a vessel ahead a lateral force occurs and the vessel begins to move in the direction, opposite to turning of the rudder, there is a turning drift angle. However the specified turn occurs in a slowed-up way, and the shifting in the opposite side for the majority of vessels is insignificant and consistent with the width of the ship and accuracy of the trace measurement. With the occurrence of a drift angle of the hull there is a hydrodynamic force, which essentially accelerates all processes, and at turn of about 180 degrees there is the movement at a constant turn rate.

As the analysis of results of sea keeping trial on more than 35 vessels shows, a dependence close to linear exists between the rate and the time of turn. In practice while manoeuvring it becomes apparent that after turning of the rudder to the given angle the vessel is as if standing. This time in navigation is named as "preliminary period of turning", and the way covered during this time is a preliminary way of circulation. The value of that time depends on the displacement of a vessel. For example for m/v The Captain Temkin in loaded condition it is within limits 42s at $\delta=5^o$,and 10s at $\delta=35^o$. For m/v " Khariton Greku" in loaded condition it is within limits 52s at $\delta=5^o$ and 5s at $\delta=35^o$.The behaviour of a vessel at handling on a steady course is determined by a kind of an initial site of the diagram of handling, which is characterised by limiting angles of negative turnability ($\pm\delta_{po}$) and turn rate of spontaneous circulation at a rudder in zero position ($\pm\omega_o$).

For the estimation of course keeping ability generalized criterion Q is applied:

$$Q= (0.5+6\omega_o)\cdot \overline{\Delta\Theta}/\overline{\Delta\delta} = n_p \cdot L \cdot \overline{\Delta\Theta}/\overline{\Delta\delta}/t/V ,$$

where n_p is the number of turns of a rudder during observation t; L is the length of the vessel between perpendiculars; V is the speed of the course; $\overline{\Delta\Theta}$ - average amplitude of yawing; $\overline{\Delta\delta}$ - average amplitude of an angle turning of a rudder. For the description of the process of the termination of circulation we apply the operational characteristics - angle (δ_m) and time (t_m) of meeting the turn, received from the manoeuvre "an asymmetrical zigzag". Advance(l_1), transfer (l_2), tactical diameter (D_t) and final diameter of circulation (D_f) are geometrical characteristics of a trajectory at circulation.

The stopability characteristics. At the existing calibration of forward (AHF, AHFm, AHH, AHS, AHDS) and back (ASF, ASH, ASS, ASDS) rotation of the engine number of all possible combinations will be 50, and in view of two conditions (in load and in ballast) - 100. Thus completely the braking properties of a vessel characterise 200 values of time and brake way. Such a big quantity of data, necessary not only to be known, but also used intelligently, presents significant difficulties for navigators. Therefore it is important to determine in which kind they should be given, for navigator to be able to take them easily into account at manoeuvring.

The basic issue, determining the value of knowledge of the stopping characteristics, is accuracy and form, in which they are submitted. Experimental-calculation method allows to get accuracy higher than 10%. The tabulated form is the most compact, which contains final values of the way and time of braking (tab. 1-3). By use of PC on the bridge for determination of the brake characteristics the specified gradation of speed loses sense, as PC calculates a brake way and time for the existing condition and speed.

Table 1 Stopping characteristics m/v Chariton Grecu

Engine ahead	AHF		AHFm		AHH		AHS		AHDS	
Engine astern	t,min	S,cbt	t,min	S,cbt	t,min	S,cbt	t,min	S,cbt	t,min	S,cbt
	In ballast condition Draft =8.05 m, Disp. = 41770 tons.									
Stop	34.7	27.02	34.0	25.45	33.8	24.92	31.7	20.98	28.7	16.85
ASF	8.2	10.27	7.6	8.7	7.4	8.17	6.3	5.72	5.6	4.06
ASH	10.7	11.95	10.1	10.38	9.8	9.85	8.7	7.24	7.8	5.25
ASS	15.4	14.63	14.7	13.06	14.5	12.54	13.3	9.71	12.1	7.27
ASDS	22.7	17.97	22.1	16.41	21.8	15/88	20.5	12.84	19.0	9.95
In loaded condition Draft=12.33m, Disp. = 66000 tons.										
Stop	55.0	42.35	53.5	38.98	53.5	38.98	49.6	32.1	43.9	24.81
ASF	10.9	14.22	9.5	10.85	9.5	10.85	7.8	6.99	6.7	4.66
ASH	14.2	16.62	12.7	13.25	12.7	13.25	10.9	9.04	9.5	6.17
ASS	20.4	20.54	18.9	17.16	18.9	17.16	16.9	12.48	15.1	8.82
ASDS	30.2	25.51	28.7	22.14	28.7	22.14	26.4	16.98	24.0	12.48

Table 2. Dispersal characteristics m|v Mikola Bajan in ballast

Existing rotation of the engine	New calibration of the engine									
	AHDS		AHS		AHH		AHFm		AHF	
	t,s	S,cbt	t,s	S,cbs	t,s	S,cbs	t,s	S,cbs	t,s	S,cbs
Stop	1253	15.5	924	15.5	691	15.5	655	15.5	593	15.5
AHDS	---	---	448	10.3	457	13.1	448	13.4	427	13.8
AHS	---	---	---	---	326	10.0	338	10.8	346	12.0
AHH	---	---	---	---	---	---	8	0.3	177	6.6
AHFm	---	---	---	---	---	---	---	---	107	4.1

Table 3 Substopping characteristics m|v Mikola Bajan in ballast

Existing rotation of the engine	New calibration of the engine							
	AHDS		AHS		AHH		AHFm	
	t,s	S,cbs	t,s	S,cbs	t,s	S,cbs	t,s	S,cbs
AHF	919	23,4	552	17.5	215	8.3	127	5.1
AHFm	874	21.7	490	15.1	18	0.7	---	---
AHH	846	20.6	448	13.6	---	---	---	---
AHS	695	14.0	---	---	---	---	---	---

On the basis of the analysis, generalization of existing methods of definition, account and presentation of the stopping characteristic classification of methods of determination of the stopping characteristics (fig. 3) was offered.

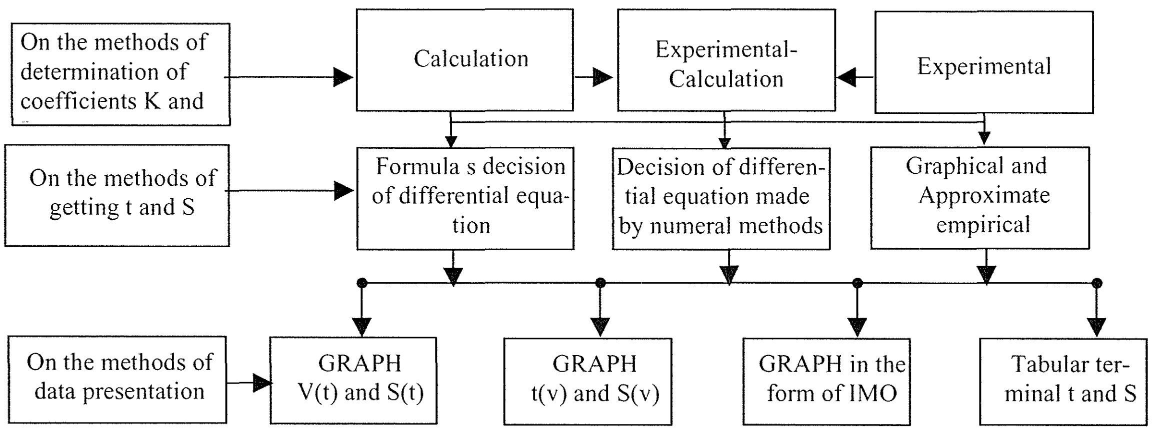

Fig. 3. Classification of the methods of the stopping characteristics determination.

The characteristics of turnability. For the representation of the characteristics through 5 degrees interval of a rudder to the right and to the left for a condition in load and in ballast total of the data, describing process of turn will make about 180. On the basis of the analysis and systematisation of existing methods of determination, account and representation classification of methods of determination of the turnability characteristics (fig. 4) was offered. For the account of the data about turnability at planning of the manoeuvre ways of pieces, perpendiculars and ellipse were developed.

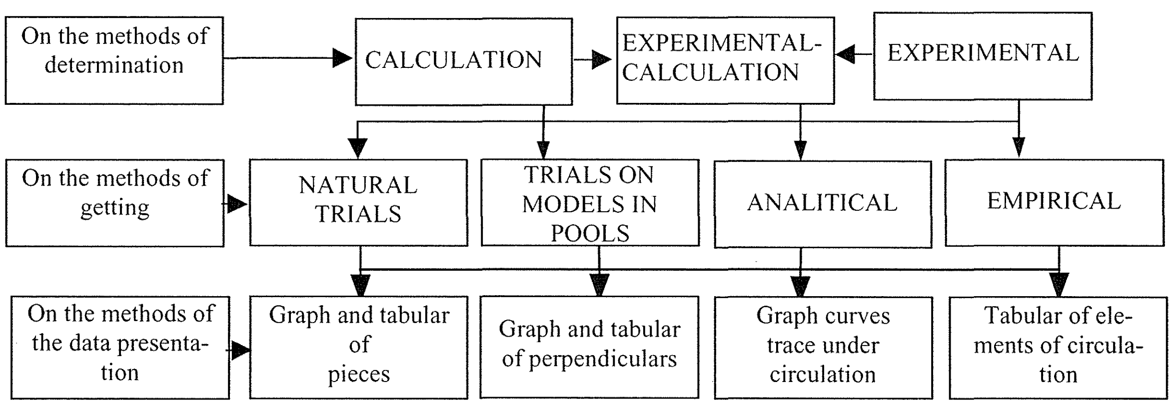

Fig. 4. Classification of the methods of the determination of turnability characteristics.

The most compact is the tabulated form of representation of the circulation given above elements. At hand-operated planning of turn it is reasonable to use the data on the characteristics as pieces, from a point of crossing of ways before and after turn (M), up to points of beginning (MB), current and ending (ME) of turn.

At automated or automatic planning of points of turn it is recommended to use way of an ellipse and perpendiculars. The essence of the way of an ellipse is in the fact that on meanings of elements of circulation l_1,l_2, D_t, D_f a trajectory of circulation with the sites of an ellipse of variable curvature. The points of the beginning of turn and intermediate ones are calculated and represented through the given by navigator interval of course as perpendiculars from the point of the ending of the turn up to the line of the initial way and from the beginning of the turn to the point crossing of the mentioned perpendicular and the line of the initial way. Having carried out binding of the specified points to geographical position of the point of crossing of ways M, we shall receive both latitude and longitude of points of the beginning and ending of the turn and intermediate points.

2. Motion controlling system of ship

From the very beginning the navigation skill was acquired solely in practice, through trial and error. With all that the process of acquisition of the specific navigation skills, as well as of knowledge, either concerning them, or the whole manoeuvring process, was too long. Many generations of captains, shipbuilders and scientists contributed to the development of the science of ship manoeuvring control. The results of theory as well as practice of ship manoeuvring control are contained in the works by many authors [1-7].

However, the process of cognition of the ship as an object of control as well as its manoeuvring cannot be considered complete. The reason for this is the great number of new types of ships, variety of tasks ships carry out at sea, and also the absence of universal systematised conception of the theory of construction of the system of ship movement control during manoeuvring.

While the collection, accumulation and generalisation of experience on manoeuvre control for various ship types is going on through trial and error, the acquisition of adequate knowledge will last long. To accelerate the process of cognition and to form necessary skills on manoeuvre control different training equipment is used, including simulators with visualisation of situation at sea. Nevertheless, accidents at sea often happen because of wrong man s actions when manoeuvring. It turns out, that he isn t prepared for operation in non-standard and extreme situations, though the equipment works well. When dealing with problems of shiphandling the questions of practical manoeuvring are usually distinguished and discussed, mainly it is the account of personal experience on carrying out one or another sea operation — mooring, towing, anchoring, storming etc. Less attention is given to ways of securing safe navigation by forming composition and structure of ship controlling system, through the knowledge of physical processes, taking place when manoeuvring. For the process of navigation, the following wording of the term ship controlling system can be suggested: totality of ship devices and elements, providing ship control when carrying out industrial tasks or manoeuvring.

The main quality of ship controlling system is its extremity. It has double nature. Firstly it means that the task of controlling is achieving of extremes of a function, which describes the condition of a controlled object (for instance, sailing from one port to another by the shortest way, in the shortest period of time and so on). Secondly the question on controlling extremity raises, through the necessity of achieving the aim of control with minimum expenditures, that is using it with maximum effectiveness (for instance, controlling by course with minimum number of helm orders, with minimum deflection from the given track). In the first case the extremity of controlling is defined by the extremity of the aims of control. In the latter one it is connected with the extremity of the controlling process itself. It means, that it must be optimal in certain sense. In such a way the controlling has some hierarchical levels, which are schematically presented on fig.5.

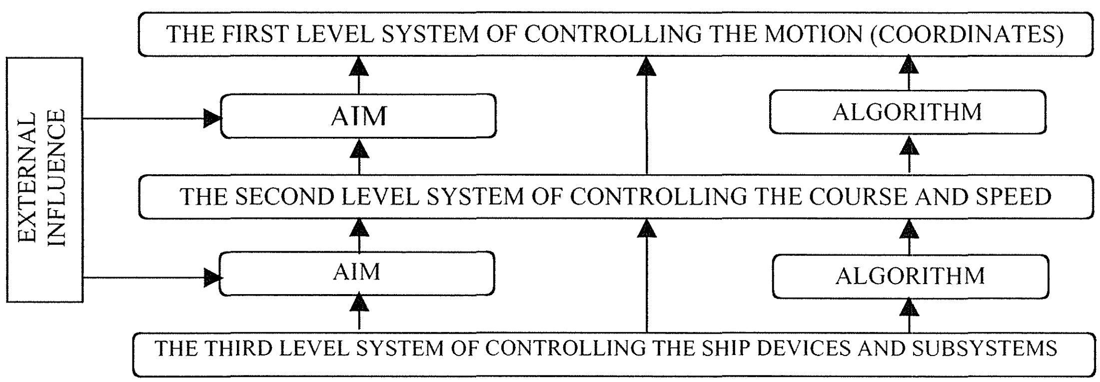

Fig.5. Block-scheme of hierarchical system of ship controls.

On differently detailed levels and using other methods, such hierarchy can be built on further. In fact, the hierarchy of ship controlling is not large and exists up to 2-nd, 3-rd level. On fig.5 we can see that controls under the influence of the 2-nd level are first of all the aim and algorithm of the 1-st level. Besides, the 2-nd level can have direct influence over the 1-st level, in order to increase its functional effectiveness. Rastrigin L.A. considers that the extreme controlling is universal and all other methods are generalised by it. As applied to the process of ship control, the system has its functional and space restraint. On one side there is a ship and its devices, on the other — environment. Two types of constituent objects can be distinguished in the system: a number of devices, elements and a number of relations. The process of dividing the system into devices and relations is called structurally [8].

In dependence on the number of devices and elements the systems can be divided into two types: simple and complex. If the system includes a large number of interrelated devices and elements of various physical nature, including man, and these elements correlate with each other in order to attain the general aim, then such system is called complex. As the contour of controlling includes man, such systems are called man-machine (MM). Thus, ship-controlling system can be defined as complex structurally MM system. It has the quality of adaptability, as it allows resolving the main problem under changing navigational conditions. For the study of the behaviour of a complex system under different working conditions, it is necessary to create its model. It should be mentioned here that despite the complexity of ship controlling system, its aim is quite clear and is described with a small number of criteria.

The complex system can be divided into sub-systems that possess certain independence but are subordinate to a single aim of the system functioning as a whole. The process of subdivision of the system into sub-systems is intended for the analyses of its functioning algorithm and the optimisation of its construction. To define the importance of a sub-system and its place in the controlling system, the consideration of two types of sub-systems— main and subordinate — is suggested. The system structur represents a fixed totality of devices and elements, as well as the order of interaction between them.

For the description of the system s functioning, graphs, structure- and block-schemes are used. For the understanding of principles of interaction between devices and elements, it is necessary to place them in order according to the existing relations and given functional task. The organisation of a ship controlling system consists of the construction of a well justified ordered distribution of ship devices and elements, together with the indication of the algorithm of their interaction, and of their order of functioning under controlling to attain the given aim.

There are structural and functional organisations. The structural organisation defines the totality and purpose of certain devices and elements. The functional organisation defines the way of subdivision of duties and interaction between devices and elements. The system s condition is characterised by the parameters describing its original state as well as the ongoing controlling process. The system is affected by the various factors usually called input values that are numerically characterised by input parameters. They can be subdivided into inner and outer ones. If the source of influence lies outside the ship, they are called outer. If the influence comes from ship devices, they are called inner. For a ship as an object of control the output values are the forces of the influence from the wind, current, waves, contact with berth, the tugs, interaction with other ships and so on. The inner values such as forces from the rudder, propeller or thrust, can be further subdivided into controllable — those, that are fixed by a navigator, and uncontrollable — those whose time and value of influence are arbitrary.

The system s reaction to these influences is described by parameters called the output. For a ship as an object of control the output parameters are kinematics parameters of the ship s motion and its position on the Earth surface. The output parameters, whose change or preservation is the aim of controlling, are called the controlled. If the controlled parameters, characterising direction and speed of a ship motion don t change, we can say that the ship is moving in an established regime. If its course and / or speed are deliberately changed, it means that the ship is manoeuvring.

System controlling consists of collection and processing of the information, and determination of the controlling influence for changing the output parameters in order to put the system in the given condition. The basis for functioning of any system, either simple or complex, is the given algorithm of its work (functioning). Without the working out of the given algorithm of system functioning , the latter s work is impossible, because the goal and purpose of the given system or sub-system is defined precisely by this algorithm. Besides, it is necessary to stress that external disturbances are disregarded when synthesising the algorithm, defined only by configuration of the area for the manoeuvring.

System s complexity is determined by the quantity of devices and elements it contains, and a number of tasks it performs. According to the number of tasks, the systems can be single-purpose and multi-purpose. The quantity of devices and elements determines the number of controlling contours flows the information flows through. The number of tasks is still more important for this determination. For instance, the sub-system of the anchor device controlling has but one aim — letting go or heaving up the anchor, and one controlling contour. Thus it is logical to call it simple.

Depending on the location of a source of influence or information, inner and outer contours are distinguished. The outer contour designates the way of passage of information whose source lies outside the ship. The inner contour stands for the way of passage of information whose source is on the ship itself.

Controlling the ship represents a multi-purpose task. Within this the aims of controlling can be of different nature and aim. They can be aimed at providing navigational safety or effective fulfilment of production tasks. Presence of man in controlling contour, during the breakdowns in the functioning system allows speaking about the influence of the human factor on the safety of navigation and working effectiveness.

On the basis of numerous ship moorings at sea (1645) and in ports (980) carried out by the author, the analysis of manoeuvre controlling system functioning was made. In accordance with the aforesaid and the results of investigation, the structure scheme of ship controlling system is suggested at fig.6.

In accordance with the given scheme, one can distinguish three main sub-systems within the system, namely Ship motion controlling , Ship technical exploitation controlling and Ship crew controlling . With a view for providing safety of navigation, the sub-system Ship motion controlling is of considerable importance. Because the consideration of all aspects of ship controlling represents a many-sided problem, later we will deal only with the sub-systems of providing navigational safety.

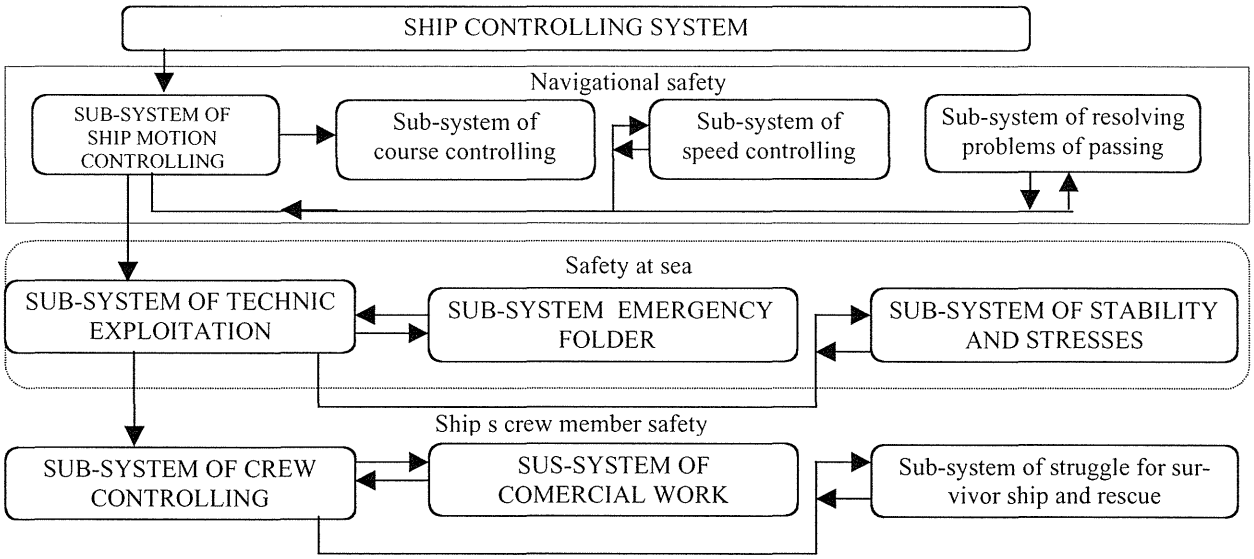

Fig.6 Structural scheme of the system Ship controlling

In a very general aspect the aim (task) of the ship motion controlling is guiding the ship along the given line of safe way defined by points on the chart, with minimum divergence. t that the way line is defined by totality of rectilinear and curved sections. The motion-controlling task can be divided into several levels namely sub-systems and contours of controlling (either outer or inner). This sub-system has subordinate sub-systems of course and speed controlling as well as of resolving problems of passing. The system of ship motion controlling can be represented by a structural scheme as it is in fig.7.*The object of controlling* is the hull of the ship, which will be represented as trajectory of a

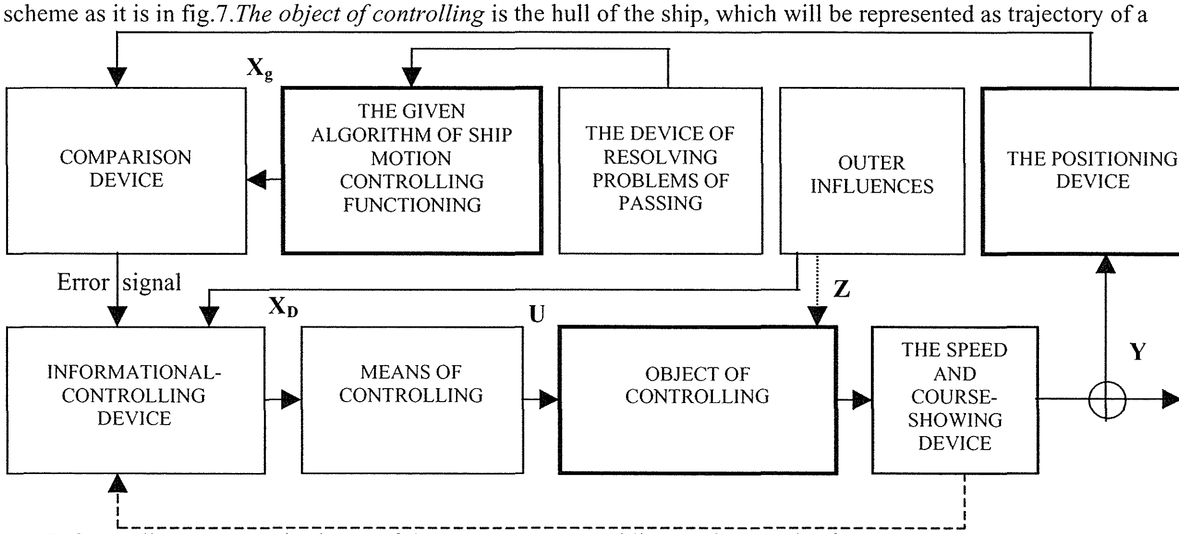

Fig.7. Generalised structural scheme of the sub-systems providing navigational safety.

point situated in the gravity centre G, when examining the manoeuvring process. *The informational-controlling device*, receiving the information of the course, speed of the ship, sea depth, values of outer influences and the error signal, works out the command on means of controlling, in order to bring the system in the given condition. Man-operator (MO) represents an element of this device.

By *means of controlling* (steering gear, propeller, steering propeller, anchor device, braking device and tugs), the controlling effect U is worked out, which brings the system into the given condition. The navigator, who is responsible for the manoeuvring process, sets the value and duration of controlling effect.

Outer influences Z — the wind (drift angle α), current (leeway from wind-induced, tidal and constant current β_t), waves (slamming, flooding), interactions (with ships during overtaking and passing in short distance, with moorage s, channel and fairway walls, with sea bottom) affect the ship and cause its displacement concerning the given line of way. There are two approaches: either the corrections for taking these perturbations into account are brought in when working out of the controlling effect; or the corrections are not calculated during the working out of the leading influence, but their effect is taken into account in the value of the error signal. In the latter case the error signal value may be so high that the controlling effect would not be sufficient to bring the system into the given condition. As a result, grounds for an accident appear. If the ship s position goes out of the admissible limits, then the accident occurs.

The given algorithm of the motion controlling system functioning is technologically defined by configuration of navigational area for manoeuvring and is represented as geographical position of the points on the chart, through which the ship should and can go when moving and manoeuvring. Usually the navigator elaborates this algorithm according to the information of the planned passage contained in the charts, pilot books and other sources. The rectilinear sections of the way are chosen, the position of the crossing points of the way line before and after a turn are plotted on the chart or entered into PC memory, the true courses between consecutive way points are plotted or calculated. To draw the curvilinear trajectories it is necessary to have the knowledge of turnability characteristics as well as of methods of plotting or calculating intermediate points position according to these values. It is necessary to mention that the algorithm does not depend on the outer influences. Secondly, the algorithm can be subject to a correction only when the navigational conditions change, which do not let to pass along the given way.

If navigator elaborates the given algorithm orally and controls the actual situation only visually, without using any technical devices, then the reliability of controlling system is essentially reduced. Usually the conflict between the captain and the pilot takes place for that reason. The pilot, on the basis of his knowledge of local conditions, elaborates the given algorithm of controlling system functioning; he actually controls the ship, while the responsibility for realisation of the algorithm lies upon the captain.

Besides, the conception of such algorithm allows explaining the reason of navigational accidents. Such definition can be suggested — The ship accident had occurred, when the controlling effect was not sufficient for bringing the ship into the given condition .

The device of resolving problems of passing works out the source data for the forming of the given algorithm of motion controlling system functioning, taking into account the presence of dangerous ships, and for its correction according to changes in situation of closing.

The comparison device evaluates the actual and given admissible position and works out the error signal X_d, in accordance with which the informational-controlling device elaborates the command for means of controlling.

If there is no comparison device and X_d signal is not worked out, then the ship will never be able to fulfil the given aim of controlling and to get to the point of destination. It is necessary to particularly stress that the motion controlling system cannot function without information of actual ship position. The sub-system of course controlling can function without information of position.

The positioning device functions on the basis of using different ways of receiving the information about the position — astronomical navigational, visual, radar, radio-navigational, satellite and others.

The speed and course-showing device determines the direction of the ship motion by gyrocompass or magnetic compass and the ship s speed by log or propeller revolutions.

The sub-system of ship motion controlling works in accordance with the following algorithm. The given algorithm of the motion controlling system functioning produces the position of points along the given way. The information of the actual position, coming from the positioning device, together with the given position go to the comparison device where the error signal X_d is worked out, the value of which comes to the informational-controlling device. The information of the previous given course, actual position, and the information of the value of outer influences also come here. On the basis of the received information the course corrections for the outer influences and devices errors are calculated, and new value of the course is determined, which brings the controlling object to the given way. Let us call the represented algorithm of the ship motion controlling system functioning as working by outer contour. The main system includes subordinate sub-systems working by the inner contour and providing the controlling of certain devices and elements. The sub-system of motion controlling and the subordinate sub-systems constitute the system of navigational safety controlling.

Process of the motion controlling sub-system functioning uses the main fundamental principles defined by methods of taking outer influences into account and using the course controlling sub-system. The consideration of the four main principles is suggested: course, course by disturbance, course by deviation and combined course.

The course principle. The structural scheme of the ship motion controlling sub-system using the course principle of controlling is characterised by absence of some elements namely the positioning device, the device of value finding and taking into account outer influences and the comparison device. During the system s operating only the course controlling system by inner contour is working. The given algorithm of functioning is worked out manually or automatically, by graphical defining or manual or automatic calculation of the ship s way; is corrected for compass errors; and then goes to the informational-controlling system, which automatically or manually conserves its value. Taking into account the influence of outer condition by means of entering corrections for their influence on the ship is not effected. It does not mean that they are absent at all, but merely their influence is not taken into account during working out of the controlling effect U of the system.

The course by disturbance principle, the course by deviation principle and the combined course principle is charac-terised by the absence of some elements, which are given on fig. 7.

The suggested system approach to the ship motion controlling allows to plan well reasonably the organisation of ship motion process, taking into account the manoeuvring characteristics, navigational situation and traffic density. The considered principles of controlling and their structural schemes, allow to create different models of ship motion controlling, analyse their functioning, synthesise the system and define its optimal structure for providing safety of navigation under different navigational conditions. Besides, such an approach allows to produce an adequate mathematical description of the process of ship motion controlling formalise and automates it [9].

3. Distribution of Responsibility

Pilot is one of the actions allowing to raise safety of ship s manoeuvring especially in congested water and dangerous areas. In International marine practice compulsory pilotage inward / outward the port is generally adopted. The only exception is small ships with local knowledge, which are liners in these areas, and ferries. Everywhere the tendency is the same — on embarking a pilot takes control of ship s navigation without submitting his actions and intentions to master s approval. Afterwards, while working together, a master can receive information of navigation conditions, arrange mooring order, the required number of tugs, traffic schedule, etc.

In case if an accident takes place with a pilot aboard the ship, he bears practically no responsibility. The deficiencies of ship s navigation operations and quick change of navigation conditions reduce the possibilities to check up pilot s actions, to clear out a mistake in his commands without local knowledge. This information is not always received in time through corresponding channels, port authorities do not inform of it when arranging ship s communication with a pilot s assistance

Analysing the present conditions of world pilot service, we can come to the following conclusions. World powers, providing for shipping safety in their territorial waters, declared pilotage compulsory everywhere. Pilotage costs have been greatly increased, they share considerable sums in ship s working expenses and are the source of port income. Meanwhile, in the case of an accident pilot is not ever guilty in general practice. Even if he accused to be guilty, he is not to hold liability for financial compensation of the accident consequences. So, his professional actions are irresponsible. If his pilotage is successful, he is evaluated as highly qualified. In case of an accident master bears his individual responsibility

Meanwhile, the procedure of ship s navigation in the congested waters causes some productive and economical risk, a master has no right for an error, but a pilot has such a right. At the same time, we don t think that pilotage is an extra service. In connection with this we d like to stress the following. It is necessary in heavy traffic areas and when entering and leaving the port. But the pressing demand is to stipulate more distinctly ships and pilot s rights duties and responsibility. The present state of facts gives evidence that a ship bears the entire responsibility and duties for the navigation, but it is not ever mentioned for ship s right and pilot s responsibility.

4. ***Conclusions and Proposals***.

Taking into account the changed condition of shipping, we propose to revise the clauses concerning pilotage. It is necessary to stipulate more precisely pilot s right, duties and responsibility, meaning that under all the circumstances he has to protect ship s interests.

Our next proposal is to carry out the distribution of Ship and pilot s responsibility in the following way. Master is to be in charge of the main engine, manoeuvring device (if any), and steering gear and for his mates and helmsman s qualification. At the same time, pilot is to bear responsibility for ship s safe navigation, with all that this implies.

With the distributed responsibility it is necessary to stipulate more precisely the moment of taking over by pilot himself the ship s navigation, with entering the date down in ship s and pilot s papers. The Pilot's contract may be as below.

PILOT'S CONTRACT

We, the undersigned pilot of port **Lattakia Nachle Intable** and Master of the m/v " "**Maria" Andrew Chircov** concluded the present contract for the first one, mentioned above, provides ship's safe navigation from/to the entrance buoy to/from port berth _10 and her mooring. Pilot bears responsibility for safe manoeuvring from agreed time moment of starting pilotage 25 January 2000 5^{35} GMT.

Master bears responsibility for right work of ship's gear and other systems, qualification of ship's personnel The second one provides proper work and qualified service of anchor, steering gear, the main engine and also strict giving of commands on ship's navigating.

All disputes on the given contract are settled upon agreement of both the parties, otherwise juridical.

The contract is composed in two copies, one of which for the Pilot, the second for the Master.

Pilot .. Nachle Intable Master Andrew Chircov

(signature) (signature)

Pilotage must be conducted for ship s interests, that s why it is necessary to think over master s opportunities who call at ports frequently and express their wish, the right of ship s navigation without a pilot. A competent master can operate his ship not worse than a pilot can. When a master is not sure, he will take advantage of pilotage compulsory. The information about manoeuvring characteristics with which vessels are supplied today according to the IMO recommendations is insufficient, as it does not cover those modes of operations of the main engine and using angles of a rudder which are used in daily operation. There are only 40 meanings of way and time of braking out of 200; for dispersal and substopping characteristics don t exist at all. And for the characteristics of turnability the data are available only as curves to the right for angles of turning the rudder of 15 and 35 degrees. The form of representation of the existing data about the braking characteristics as the IMO linear diagrams and about turnability is inconvenient for practical use on the bridge.

It is offered to reconsider the program of tests of the vessels after construction, by providing as minimum quantity obligatory manoeuvres: asymmetrical zigzag (characteristics of meeting the turn, zone of instability, diagram of handling); passive and active braking (the definition of the maximum force of a thrust of the screw for modes ASF,ASH,ASS,ASDS and is desirable no less than three times each); circulation to the right and to the left for angles of turn of the rudder on 5,10, 15,20 and 35 degrees at the speed of complete forward manoeuvring and AHH; dispersal from a motionless condition up to AHDS, AHS, AHH, AHFm, AHF; circulation to the right and to the left for an angle of turn the rudder on 15 degrees at an astern movement; passive, active braking and circulation on the shallow water; asymmetrical zigzag on the shallow water. All data about manoeuvring characteristic should be represented as a separate folder " The Information to the captains about the manoeuvring characteristics ".

Account of a way and time of braking, dispersal and substopping should be made by an experimental - settlement way, and results to be represented as the tables for the bridge and in any other kind, required by the normative documents. To present the offers to IMO about realisation of an international conference on providing vessels with the data about the manoeuvring characteristics in view of the last achievements of science and engineering.

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