# Research On Advancing Informational Support During Shiphandling In Congested Waters

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## ABSTRACT

The given research will help the navigator to be trained fully in accordance with:

- STCW – 78-95, Code STCW –95
- SOLAS 1974 as amended
- IMO Resolutions A. 224(7), A. 282(8), A.342 (9), A.424 (11), A.477 (12), A.526 (13), A.529(13), A.574(14), A. 575(14), A.665(16), A.694(17), A.817(19), 823(19).

Despite the fact that real-time simulating equipment (e.g. Full Mission Ship Simulator - FMSS) is in use all over the world for training navigators and navigational cadets, manned physical models of large capacity allow us to carry out various tasks of Shiphandling in congested waters, in environments, much more closer to real-life conditions than any computer-based simulator ever built. Such manned model ideally imitates ship's maneuvering in congested waters, where due to transience of all processes, most navigational control tools cannot be used. The navigator should then evaluate the situation "by eye", and "by feeling". Control and decision-making is based on dynamics of changes in the environment/surrounding conditions. Assessment of a ship's hydrodynamics and applied forces is essential - when analyzing such an environment.

In order to carry out the research we have performed following activities:

- Imitated navigational area's environment
- Developed ships' maneuvering scheme algorithm
- Designed model of ship's maneuvering control
- Emphasized ergonomic and psychological aspects of navigator's activities

Main results of the research are:

-Increase navigational safety due to higher level of Shiphandling training.
-Received results serve for designing ships' maneuvering system and for choosing its structure.
-Offered combined training program for navigational officers using manned models and FMSS.

### Introduction

One of the most important aspects of solving the problem of safe navigation in congested waters is the profound knowledge of ship's properties as an object of control. The possession of this knowledge by a navigator, in addition to good practical skills, allows him to control the ship more efficiently under different conditions of navigation, which results in decreasing accident rate in the shipping industry.

That is why a very important problem consists in obtaining the information concerning the elements of ship's maneuverability with the further usage of the above information in the process of simulator training of ship control. The acquisition of the required information may be effected by both physical and model trials. The latter ones are especially important for the sake of accumulation of statistic data concerning the ship's behavior when performing a certain maneuver.

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Standard training and implementation of model trials requires the maximum possible similarity of the models to the prototype ships. Since the efficiency of the navigator's simulator training depends, to a considerable extent, on the profundity of the theoretical knowledge of ship's dynamics, an acute necessity arises to prepare the full amount of the data reflecting the principal peculiarities of ship's behavior under different conditions of maneuvering.

The accumulation of a sufficient amount of statistical data for acquiring ship maneuvering process quantitative assessment requires considerable expenses and time. As already mentioned above one of the possible solutions of the problem is the application of physical modeling methods.

**1.The ship process maneuvering modeling method.**

In Odessa National Maritime Academy (ONMA) large scale manned models of LNG carrier "Mossoviet" and bulk carrier "Khariton Greku" are used for this purpose. A series of trials of the model of m/v "Khariton Greku" was effected aiming at the investigation of the ship's behavior in the maneuvering process in particular, the determination of the transitional curve shape when the ship enters the circulation. In the trial process the model path, the course angle in relation to a conspicuous object when the ship was moving with the predetermined rudder-deflection angle were fixed. Altogether 47 experiments have been made (18 for rudder deflection angle of 30° to port and 15° for rudder defection angle of 30° to starboard included) in different weather conditions (wind, rough sea) 0-3 when brought to the scale of a real ship. Model path measurement precision using the method of theodolite marks is estimated with the root mean square course error of 6-12 cm., the course angle measurement accuracy is 0.5°. The processing of the natural observations data allowed to obtain the information concerning the (PP) model movement path, alterations of the course, speed, angular speed, drift angle and the path curvature (K) for every experiment instance and also the fluctuation of mean values and root mean square errors of the above parameters for every group of experiments (rudder deflection angles). The information about the fluctuations of the path mean average curvature values and their root mean square errors and the course for the ship's movement in circulation with the rudder deflection angle of 30° to port and starboard are given in Figs 1. and 2.

The obtained in the experiment dependences of turning path curvature of the course angle and the distance covered prove the theoretically obtained expression for the current radius of turning $\nu_i$:

$$\nu_i = R_0 \frac{\sqrt{\varphi_0}}{\varphi_i}$$

where $R_0$ – radius of constant turning.

$\varphi_0$ - course angle causing providing for circular path formation.

The notion of ship turning is to be regarded as a probabilistic process. The practice of ship's control proves the fact that the fulfillment of turning the ship in similar conditions and by means of identical control actions results as a rule not in a single path but in a whole band covering a number of paths. The width of this band in the vicinity of course change by 90° in relation to the previous one (in the point of rudder turning) is comparable with the ship's hull length. The hypothesis of the probabilistic character of ship's movement during the turn was proved experimentally during the physical trials of m/v "Captain Polkovskiy" and "Yargara".

A similar work was fulfilled on board bulk carrier "Khariton Greku" although the amount of operations was rather limited as compared to the previous one. The arrangement of trials and the weather conditions practically completely excluded the influence of the external interferences on the process of ship's movement along the curved path. There were effected altogether 6 turns with the change of the course by 90°-100° in relation to the initial direction of movement with the rudder deflection angle 15° to port. As the experiments proved (you may see the paths of turning on Fig. 3) again, a whole band of paths was obtained in spite of the limited number of maneuvers. For the evaluation of the dispersion of paths in small samples (the number of samples range from 2 to 12) it is recommended to use the scope that facilitates although not very efficient but quite acceptable evaluation of the product of the standard divergence by the known multiplier of general totality (aggregate). The scope of paths (or the formed (by the paths) band width) in the vicinity of rudder turning equaled 0.45 kbt (83.44m) or 0.41 of the ship's hull length.

Thus, the above model trials and physical experiments with the real prototype ship vividly visualize the probabilistic character of principal cinematic parameters change during ship's maneuvering. Consequently, when planning ship maneuvers, one should not speak about an assumed path of ship movement but with a certain probability degree about a whole band of possible ship movement.

The comparison of inertia-braking characteristics of a model and a prototype ship shows that relative difference of braking paths for the maneuver of FSSA-FSA may amount to 12%, but one should take into account, - that the movement at full speed when maneuvering in congested waters is practically not applicable, that is the above maneuver for the manned model is not practicable. In all the rest of the maneuvers where active braking is effected the difference is less than 10% and that gives evidence of a good accordance of the inertia-braking characteristics of a model with those of the prototype ship. A clear view of that accordance is given by means of the graphs of speed and the braking path of the ship and the model presented in pairs on Figs 3-9.

## 2. Research and training.

In the process of the above investigations the planned researches with the use of manned ship models aimed at the processing of certain elements of ship movement modeling and setting of simulation problems were combined with training of refresher-courses navigating officers groups.

The essentials of the methods of this sort of training were developed during investigation. The quantitative forms of assessment and monitoring of the listeners progress were also proposed in that process. But the full - scale practical application of this method of assessment in practical training is hindered by the absence of certain instrumentation the necessity of a great number of measurements and, most importantly, their processing. That is why it doesn't suit nowadays for operational practice of simulation training process but is used for the preparation of the problem in the process of its setting up identification. On today's stage maneuver zone parameters are determined for every category of assessment. Further on in the process of simulation lessons the maneuver zone dimensions obtained in the task fulfillment are to be compared with those of the standard pattern zone. As we can conclude from the above, any judgment of the maneuver zone drawn from one experiment would be false, as the parameters are characterized by the statistic divergence. The reliable and objective means of the exercise fulfillment monitoring would be video record of the process. A joint viewing of the record together with the instructor right after the training cycle would enable the listener to give a proper assessment to his actions (taking into consideration the normal statistic divergence) observing ship model movement against a background of navigational buoys and marks imitators, hydrotechnical facilities and other objects depicting the aquatorium, to express the geometric parameters of the ship's hull dimensions (length, width of the hull, etc.). The maneuver kinematics e.g. changes of the angular speed when turning, the stern throw, the change of the ship's position in relation to the wind etc.

**3. Training method**

The training procedure is as follows: preliminary theoretical instruction in the classroom with the whole group to be present. Full Mission Ship Simulator (FMSS) is to be used at these lessons. Then the group is subdivided into "crews" containing 2 persons each, who in turn occupy the positions of navigator and engineer-helmsman. In the process of exercise fulfillment at every model the orders are given from the "bridge" and the "engineer-helmsman " carries them out without any interference in the control process.

During the classroom lessons the students get acquainted with the required theoretical sections of the ship-handling course, the notion of controllability of the ship with the particular inertia-braking characteristics, when a man-operator acts in different navigation-hydrographical and hydro-meteorological conditions. The students are also introduced to the main principles of ship navigation simulation and rules of their operation, aquatorium facilities, the conditions of simulation exercises and the order of their fulfillment, the accumulated experience of simulation and the peculiarities of the usage of manned models for training the tasks of safe navigation.

The practical training is affected with separate "crews" which in succession fulfill the tasks for the day prepared to solving the forthcoming problems by means of a situational analysis. They are also instructed in the technique of model control. Every exercise is performed not less than three times. After every exercise the instructor can give, if required, his remarks and recommendations. Analysis with the crewmembers is done after every cycle of exercise repetitions and a joint group analysis after every cycle of problems.

After the performance of a block of exercises every students is to solve a complex attestation problem, including elements of various problems. A very advantageous element of training proved to be the observation and analysis of the actions of a colleague, performing an exercise by a group of training navigators.

Practice shows that the instructor should by no means impose his own scheme of exercise fulfillment on the students. His role should limited to setting the problem, instruction in control, recommendations of the tactics of maneuvering, and observation and joint analysis of the results. His direct assistance may be necessary during the time of students adaptation to the model (1-2 first period) or in case of series of fails when the navigator starts feeling constrained and uncertain.

ONMA's method of physical modeling (simulation) of different sailing conditions using manned ship models and methods of training and investigation gives an opportunity not only for the investigation of any particular conditions of navigation (and on the basis of the analysis of the above investigation to prepare practical recommendations) but also to help the navigators (masters, chief officers and pilots) to develop the habits (skills, abilities) to handle the ships in congested waters. Multiple repetitions of maneuvers in different situations facilitate the strengthening of these skills and the experience of safe maneuvering.

Analysis of the acquired experience shows that the correct arrangement of the lessons, combining the survey theoretical instruction (FMSS included), practical exercises on water with observation from the shore and recording of all the actions by the video-tape-recorder provide positive results in two directions:

First, in compliance with the requirements of STCW-78/95 Convention, Regulation II-2 and IMO Resolution 17 the navigators acquire practical skills of handling ships when sailing in congested waters. An important component of this training is modeling (simulation) not only of safe navigation, but also emergency situations, for the reproduction of which the simulator is the only possible means.

Second, comparing the requirements of safe navigation criteria and an actually observed situation on the aquatoria, when the tasks are worked out at the imitator-simulator, a navigator acquires the skills of situational analysis (i.e., preliminary study and planning of the maneuvers, determination of critical values of the ship's movement, the limitations of the navigation conditions caused by the forces of the environment). The choice of the navigation tactics is made on the basis of the preliminary situation analysis in the aquatorium.

**Conclusions**

The principal peculiarity of the simulation problems in question is their relative complexity and that of the methods used the systematic repetition of the training problems, i.e. the method of "attempts and fails". The solution of simulation problems was often affected under hard conditions of the influence of extreme hydrometeorologic conditions.

In parallel with model investigations, the steering of ONMA training vessels through the Bosphorus in very heavy conditions of navigation was done. The obtained results give us grounds to conclude that efficiency of the navigator's work when sailing along complicated straits is low. These conditions prove the acute necessity of developing means and methods of steering that would eliminate the trespassing of dividing and boundary lines, and simulator training of such methods of steering.

Analysis of the results of a simulation problem concerning steering through a rectilinear shallow channel shows that the navigators comparatively quickly acquire the necessary skill that they retain for a year. The statistical data obtained facilitated the development of an analytical model of ship's steering through a channel in different hydro-meteorological conditions, which has its proper specialization – theoretical essentials of conception instruction.

Complicated simulation problems (e.g., "making fast", or "turn in narrow waters") were the most time-consuming in the process of training. The obtained results provide the opportunity for tracing the dynamics of trainability; - however, the experimental data still remain contradictory. When the problems are being worked out the absence of the methods of navigators' psycho-physiological state check-up (fatigue, high emotional stress, information overflow etc.) as well as the used training method of "attempts and fails" (which is rather time-consuming) are the factors that contribute to the contradictory character of the data. But at the same time this method enabled the instructors to determine the initial level of practical knowledge and skills of the navigators, participating in the experiment and facilitated the identification of the way to more effective training, which in our opinion should combine practical knowledge and skills.

Thus, further improvement of the training methods will proceed in the described direction and the training exercises will include complicated critical situations and working skills that cannot be formed in real conditions.

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