Fairway determination with simulation method as illustrated by the Port of Gdansk
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Abstract

The determination of fairways can be carried out by means of a few methods. The modernization of fairways on the existing port areas is usually very difficult, due to the existing infrastructure. Each increase in waterway dimensions results in the necessity to correct a coastline, which is connected with increased expenses. Apart from that, there may be instances in which a change of coastline is impossible.

The application of a simulation method in such a situation makes it possible to collect a great amount of statistical data the analysis of which enables to define fairway parameters. At the same time, it is possible to specify safe operation of the fairway. The paper presents the method and the results obtained in the process of determination of the fairways in the port of Gdansk.

1. Introduction

There may be observed a constant tendency to increase the sizes of the vessels handled in ports. If causes a necessity to modernise fairway parameters to match the increased dimensions of vessels. The modernisation calls for defining the correction of fairway limits for preset conditions: vessel’s size and hydrometeorological conditions. If the
local conditions do not allow to rebuild a part of the fairway, it is necessary to define boundary conditions of safe operation.

One of the basic methods of determining fairway parameters is a deterministic method, based on suggestions and instructions taking into account the corrections for the factors affecting vessel’s movement. In the case of determining a fairway width by means of a lane width of vessel’s movement, the number of factors to be considered may amount to several [1]. Each factor is considered in relation to vessel’s breadth. The method is easy to use; however, it does not consider accurately the conditions on a given area and, as shown by experience, in many cases it overstates the traffic lane required. Apart from, it the quantitative evaluation of safety is made difficult, which makes it impossible to evaluate a navigational risk.

For this reason, a more adequate method is a probabilistic method of determining fairway parameters. While determining a fairway width, it undergoes a multiple observation of traffic lane widths in the process of trials by particular vessels. The set is processed statistically in order to determine distribution types and parameters, which makes it possible to define a safety level of fairway [3]. It enables to apply the figures to active management of safety. The collection of proper data is done by means of simulation tests. They make it possible to examine many alternatives of the planned modernisation and the choice of an optimum solution [4].

2. Subject and Range of Research

The research subject is the planned modernisation of the port of Gdansk – Nowy Port. Its aim is to ensure a possibility of entering the port by vessels of 250 and 300m length. The fairway in the port of Gdansk may be divided into the transit canal in the Bay of Gdansk and the port canals running generally along the old bed of the Vistula River.

The analysis of navigational conditions carried out on the approach and in the port canals, for the planned operation of maximum vessels \( (L_1=250 \text{ m}, B_1=35\text{ m} \text{ and } T_1=10.5\text{ m} \text{ as well as } L_2=300\text{ m}, B_2=46\text{ m} \text{ and } T_2=6\text{ m}) \), has shown that in some sections of the fairway, keeping a proper safety level may be impossible.

For the pre-set parameters of maximum vessels, there have been defined parameters of the designed fairway (depths, widths, arc radii, turning basin diameters) based on the deterministic methods used for
designing waterways. Additional limitations included in the designing process were:

- the quays whose rebuilding or destroying is out of question,
- objects or constructions whose rebuilding or destroying is impossible for other reasons than direct operation (historical buildings, cable culverts, ferry crossings),
- suggestions by the port users.

The planned simulation tests were carried out for the four presented sections of the fairway of the Port of Gdansk.

3. Research Method

Simulation tests were carried out by means of a constructed computer model based on the PC computer. The model includes; a model of vessel’s movement, a model of the area and navigational marks, a model of hydrometeorological conditions and a console (Fig.1).

![Computer screen with simulation model.](image)
The model of vessel’s movement comprised two types of vessels. The hydrometeorological conditions comprised wind (no currents in the fairway) of speeds of 5 and 10 m/s and of the directions unfavourable from the point of view of vessel’s manoeuvring. For the section comprising the port entrance, the manoeuvres of entering the port by a vessel of 250m were carried out with a bow and a stern. Also, while leaving the port, the manoeuvre of doing it with a stern was tested. Such kinds of tests resulted from the current and planned operation of the port. For the quays situated near the port entrance, the vessel can be brought in with a stern since the only turning basin enabling vessel’s turn of this type is the Main Port Turning Basin situated far in the port. All vessel’s manoeuvres are done with the assistance of tugs whose number is defined by port local regulations.

In the process of simulation tests, the data were registered automatically. The obtained sets were processed statistically. The number of trials in a series for the same conditions is credible for the tested alternatives defining the problem being solved. The comparison of the alternatives and the analysis of the results are carried out with the help of navigational safety criteria.

4. Research Results

The research results have been presented in a form of the following charts and diagrams:
- Lanes of vessel’s movement – Fig. 2.
- Frequencies of vessel’s occurrence in the position – Fig. 3.
- Distribution of vessel’s longitudinal speed – Fig. 4.
- Distributions of vessel’s angular speed – Fig. 5.

The width of the traffic lane is determined by a random variable representing maximum distances of extreme vessel’s points on the right and left sides of the hypothetical axis of the accepted coordinate system. The width of the traffic lane for a specified series of trials is calculated with a method of parallel lanes on the level:
- mean,
- maximum as a maximum envelope curve of a specified series,
- of confidence equal to 95%.
Fig. 2. Port entrance. Area of heads. Movement lanes of a bulk carrier 300m long. Wind E 5 m/s.

Fig. 3. Port entrance. Area of heads. Frequencies of occurrence of a vessel 300m long in the position. Wind E 5m/s.
Fig. 4. Port entrance. Distribution of a longitudinal speed of a bulk carrier 300m long. Wind E 5m/s.

Fig. 5. Port entrance. Distribution of an angular speed of a bulk carrier 300m long. Wind E 5m/s.
Frequencies of vessel's occurrence in the position present multiplication factors of a stay of any vessel's point in any area square for tested measure series. The measurements of the square have been assumed to be 5 m. x 5 m. For example, the reading of the multiplication factor "2" for the square interesting for us means that during the series of 10 trials in this square, any vessel's point was in the course of 2 trials. Frequency diagrams make it easier to analyse the trajectory of vessel's movement for the tested series and serve initially to verify trial quality.

The speed distributions make it possible to analyse manoeuvring tactics of vessels in particular parts of the examined areas. Apart from it, they enable to work out a set of instructions and tips ensuring safe maneuvering in the future.

5. Result Analysis

The conducted simulation tests on movement of vessels 250 m. and 300m. long in the port of Gdansk make it possible to carry out an analysis in the aspect of navigational safety. The alternatives of the conducted tests took into account the specificity of the problems occurring in shipping for vessels of such a size.

The approach fairway, for the vessels brought in the port and having a length of 250m and 300m., is determined as an outline of a new approach fairway, obtained on the basis of traffic lanes.

The port entrance assumed the shifting of the western breakwater by about 60m westward. The simulation test results make it possible to formulate the following detailed remarks:

- Resultant traffic lanes of vessel 250 m and 300 m long define precisely the shape of a required fairway,
- the width of the fairway for vessels of 250 m is safe,
- for vessels 300m long the width of the fairway is not sufficient in 3 places
- simulation traffic lanes refer to vessel's entering and leaving with a bow, as well as unfavourable cases of bringing vessels in and out with a stern.

The Turn of Five Whistles. The conducted simulation tests assumed vessels continuous movement as well as the introduction of limited changes of the coastline. The resultant lanes of movement of the vessel 250 m and 300m long specify a required location and parameters of the fairway. The maximum width of traffic lanes for vessels of 250 m and
300m long is similar and amounts to about 160m. The difference between the results obtained for these vessels is caused by the fact that the vessels 250m long are characterised by a relatively continuous traffic lane generally with one exception – a safe lane. The vessel 300 long, however, lacks a continuous movement, which brings about dangerous situations.

The main Port Turning Basin at G.S.R. The conducted simulation tests defined required areas of manoeuvring in the Turning Basin for the preset vessels and hydrometeorological conditions. The areas show that a vessel 250m long may be turned safely in the current conditions introducing some minimal restrictions. However, turning the vessels 300 m long brings a big risk. Safe turning of such vessels requires the correction of the coastline.

6. Summing up

Designing a fairway in the existing port areas is always connected with a certain compromise. The compromise takes into consideration the relations between the parameters of the existing water area and the parameters of a maximum vessel planned to be operated. It is accepted in order to specify a level of navigational risk. Assuming that a navigational risk is smaller means increasing the parameters of the fairway and increasing the cost of its construction and operation.

The working out of a concept of modernising the fairways of the Port of Gdansk has been stimulated by the need to handle bigger vessels in the port and the repair shipyard. For this reason, the consideration comprised two groups of vessels different in terms of length overall and maximum draught.

The application of the simulation research method made it possible to carry out many trials of manoeuvring simulations on the fairways actually not existing. The trials were performed for vessels of different sizes and for selected meteorological conditions. The level of difficulty in modernising the fairways in the port of Gdansk results not only from a high cost of the undertaking but it is also strongly limited by the existing structures of historical value. For this reason, it is so important to establish safe fairways for the vessels of a planned size, preserving some parts of the existing structures and at a pre-set level of navigational risk.

The conducted simulation tests made it possible to define three safe lengths in the most dangerous parts of the fairway. The suggested parameters refer to the approach channel, the Turn of Five Whistles and the Main Port Turning Basin. The dimensions of the manoeuvring areas were established on the basis of the statistical areas at a level of 0.95.
Taking into consideration the authors’ own experience as well as similar works done in the world, a statement may be risked that the use of simulation methods to support the process of designing fairways and ports is very effective. At relatively small financial expenses, it is possible to conduct complex research. The obtained and registered results can be used for various calculations and multi-criteria analyses. It is possible to take into account a navigational risk as well as, in interactive models, such a difficult element as a human factor.

Summing up, it must be said that:

- The use of computer simulation method to establish fairways is cheap and effective,
- The conducted simulations make it possible to change vessel’s parameters, area and external factors,
- A great number of the results obtained makes it possible to carry out a multi-criteria analysis taking into account a level of navigational risk,
- The simulation of vessel’s movement can be used to support the process of fairway designing,
- The analysis of the results obtained for the alternative of the fairway being realised makes it possible to formulate port regulations.

7. Bibliography


