STANISŁAW GUCMA, Assoc. Prof., D.Sc., Sea Capt.
Maritime University, Szczecin
Institute of Sea Navigation

Ship's manoeuvring water region - methods of determination

SUMMARY

The determination of mutual relations between ship, water region, hydrometeorological conditions and position finding system depends on kinds of waterway and manoeuvre being made, for which different methods of defining safe manoeuvring water region are used.

The paper presents some methods of defining a safe manoeuvring water region, applied in navigation practice and designing waterways. Some contemporary simulation and optimization methods are also discussed which make it possible to define safe manoeuvring water region for ships in terms of shipping safety criteria. Such elements of waterways as the fairway, port entrance, anchorage, turning area and port basin are considered.

The paper presented at the International Symposium on Manoeuvrability of Ships at Slow Speed -„Manoeuvrability'95" , Ilawa ,1995

INTRODUCTION

The manoeuvring safety in limited water regions can be determined by using the following evaluation criteria:

- size of manoeuvring water region (1)
- amount of water under keel (2)
- speed of discharge current at the bottom (3)
- kinetic energy of ships impact on the quay (4).

The manoeuvring safety criteria may be generally expressed, assuming that the tested ship manoeuvres in the limited water region where the position is defined by the rectangular coordinates $x \in X$; $y \in Y$, as follows:

$$D_{ijk} \subset D_{ij} \subset D_i \subset D \qquad (1)$$
$$i \in N;\ j \in M;\ k \in P$$

$$R_{ijkxy} \geq H_{xy} - T_j \qquad (2)$$
$$x \in X; y \in Y$$

$$V_{ijkxy} \leq V_{xy} \qquad (3)$$

$$E_{ijkr} \leq E_r \qquad (4)$$
$$r \in L$$

where:

D_{ijk} - point pattern which determines a manoeuvring water region of j-th type of ship for i-th kind of manoeuvre and k-th set of navigation conditions
D_{ij} - safe manoeuvring water region of j-th type of ship for i-th kind of manoeuvre
D_i - safe manoeuvring water region for the M set of ships for i-th kind of manoeuvre
D - accessible manoeuvring water region of the ship which meets the criteria of permissible depth (2) and discharge current speed at the bottom (3) for each point (x,y) of the D set
N - set of accessible manoeuvres for j-type of ship
M - set of ships
P - set of possible navigation conditions
R_{ijkxy} - safe amount of water under keel of j-th type of ship in x,y point of region for i-th kind of manoeuvre and k-th set of navigation conditions
H_{xy} - depth of water region in x,y point
T_j - draught of j-th type of ship
X - set of x
Y - set of y
V_{ijkxy} - safe speed of discharge current at the bottom in x,y point for i-th kind of manoeuvre of j-th type of ship and k-th set of navigation conditions
V_{xy} - permissible speed of discharge current at the bottom in x,y point
E_{ijkr} - safe kinetic energy of impact of j-th type of ship on the quay in r-th point for i-th kind of manoeuvre and k-th set of navigation conditions
E_r - permissible kinetic energy of ship impact in r-th point of the quay.
L - set of the points of the quay where ship impacts can be expected

The safe ship manoeuvring region defined by means of a traffic lane width depends on kind of the manoeuvre being made connected with an element of the waterway on which the manoeuvre takes place. The following elements of waterway and the manoeuvres connected with them are distinguished:

- Fairway (straight line length, fairway curve) - manoeuvre of proceeding along fairway
- Entrance to port or port basin - manoeuvre of entering the port
- Turning basin - manoeuvre of turning
- Anchorage - manoeuvre of anchoring
- Port basin - manoeuvre of berthing.

The size of a ship manoeuvring region also depends on the navigation conditions prevailing over the region in question, which comprise:

- hydrometeorological conditions (winds, currents, waving, icing, visibility)
- selected ship operating conditions (manoeuvre being performed, number of tugs, their parameters, towing lines etc.)
- navigation marking of the region.

A safe manoeuvring region of j-th type of ship for i-th kind of manoeuvre is defined by using the dependence:

$$D_{ij} = D_{ij1} \cap D_{ij2} \cap D_{ij3} \cap \ldots \cap D_{ijn} \qquad (5)$$

$$n \in P$$

where:

D_{ijn} - point pattern which defines a manoeuvring region of j-th type of ship for n sets of navigation conditions

A safe manoeuvring region of all types of ships from the M set for i-th kind of manoeuvre is:

$$D_i = D_{i1} \cap D_{i2} \cap D_{i3} \cap \ldots \cap D_{im} \qquad (6)$$

$$m \in M$$

where:

D_{im} - point pattern which defines a manoeuvring region for m types of ships

The quantities D, H_{xy}, V_{xy}, E_r, are constant for a specific manoeuvring region and can be changed only in the case of its modernization. D_{ijk}, R_{ijkxy}, V_{ijkxy} and E_{ijkr} are variables which depend on a number of various factors, and that is why some of them are difficult to be determined exactly.

The variables are defined, depending on the problem being solved, by means of empirical or model methods, the latter comprising a computer simulation method which is most widely used at present [3].

SHIP'S MANOEUVRING REGION

The size of ships manoeuvring region D_{ijk} depends on such factors as:

- ship's parameters
- water region parameters
- type of performed manoeuvre
- hydrometeorological conditions
- ship's operating conditions
- navigation conditions
- pilot's and captain's qualifications.

The manoeuvring region can be determined , depending on the problem being solved, by using empirical methods or computer simulation methods.

Empirical methods provide approximate results and may be used in the navigational practice by making an analysis of possible performance of a specific manoeuvre (e.g. an analysis of possible proceeding along a dangerous length of the fairway, entering the port etc.). Computer simulation methods are accurate and are used in:

- designing and modernizing waterways
- designing ships for operation in specific water regions
- defining ship operating conditions in specified water regions as well as
- designing navigation marking systems.

The Institute of Sea Navigation of Maritime University in Szczecin worked out a number of computer simulation methods used to determine size of manoeuvring regions of various kinds of waters. All the methods are based on a simulation analysis of manoeuvres to be performed. The manoeuvres are simulated on the following vision simulators:

- NORCONTROL NMS-90 vision simulator
- vision simulators built from PC computer components by the Institute of Sea Navigation.

The simulation manoeuvres are carried out in series of a credible number Specific series are carried out for identical hydrometeorological, operating and navigation conditions. The manoeuvres are performed by navigators (captains, pilots) of usual qualifications.

One of the methods of determining the manoeuvring region is the method consisting in defining the width of ship's movement path.

The manoeuvring region is divided into z paths of the constant width Δb, and a hypothetical axis of the region is specified in relation to which maximum distances of ship's extreme points to the left and right for each manoeuvre in each ship movement path are calculated [2,3,5].

$$h_j = \overline{x_{lj}} + c\,\delta_{lj} + \overline{x_{pj}} + c\,\delta_{pj} \qquad (7)$$

where:

h_j - movement path width in j-th path of the region;

$\overline{x_{lj}}, \overline{x_{pj}}$ - mean values of maximum distances of the region extreme points to the left and right of the axis in j -th path of the region, respectively;

$$\overline{x_{lj}} = \frac{\sum_{i=1}^{n} x_{lij}}{n} \qquad \overline{x_{pj}} = \frac{\sum_{i=1}^{n} x_{pij}}{n} \qquad (8)$$

δ_{lj}, δ_{pj} - standard deviations of maximum distances of ship's extreme points to the left and right of the axis in j-th path of the region, respectively;

$$\delta_{lj} = \sqrt{\frac{x_{lij} - \overline{x_{lj}}}{n - 1}} \qquad (9)$$

$$\delta_{pj} = \sqrt{\frac{x_{pij} - \overline{x_{pj}}}{n - 1}} \qquad (10)$$

c - confidence level coefficient

$i, j \in$ set of natural numbers

The calculations are usually carried out with the significance level of $\alpha = 0.05$ and normal distribution assumed as the model for the random variable (maximum distance of ship's extreme points to the left and right).

One of the problems solved by the Institute of Sea Navigation consisted in estimation of maximum ship parameters of a universal ferry which could safely enter the port of Ystad [8]. On the basis of simulation tests it was possible to find the parameters of the ferry, called „Ystadmaks", for which the manoeuvring region during berthing (at NW and SE winds of 20 m/s) is presented in Fig.1. On this basis the ferry, „Polonia", was designed and built.

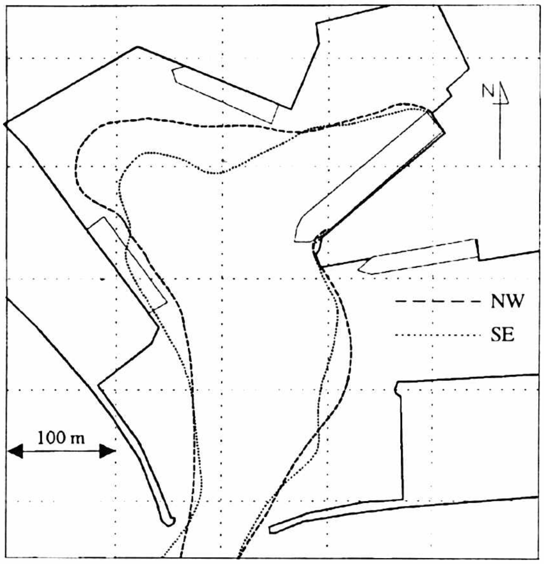


Fig.1. Manoeuvring area of m/f „Polonia" for berthing in the port of Ystad (wind of 20 m/s, NW and SE)

Similar methods were used for designing the Pomeranian Fuel Terminal in Świnoujście. A shape of the port terminal basin (see Fig.2) was designed on the basis of simulation tests carried out for 60 000 dwt tanker [1,5].

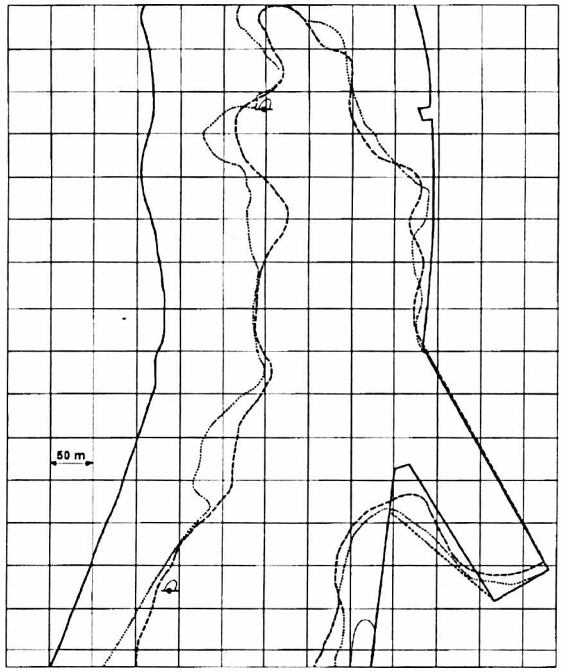


Fig. 2. Manoeuvring area of 60 000 dwt tanker for berthing in the Pomeranian Fuel Terminal at Świnoujście

limits of manoeuvring area of 60 000 dwt tanker
limits of manoeuvring area of tug operation
new (optimal) shape of port basin
old shape of port basin

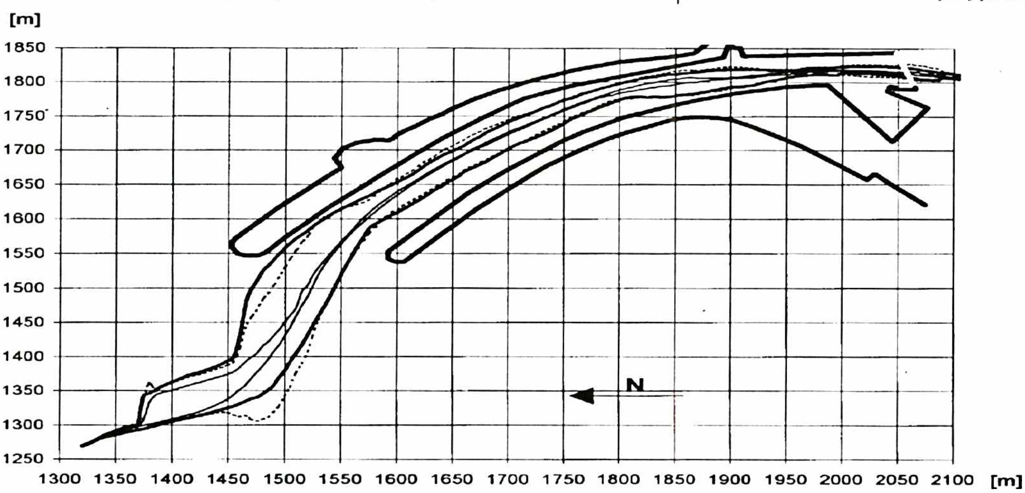


Fig. 3. Manoeuvring area of 100 m ship entering the port of Kołobrzeg

average
max. envelope
probability 95%

current velocity [m/s]
6-7
5-6
4-5
3-4
2-3

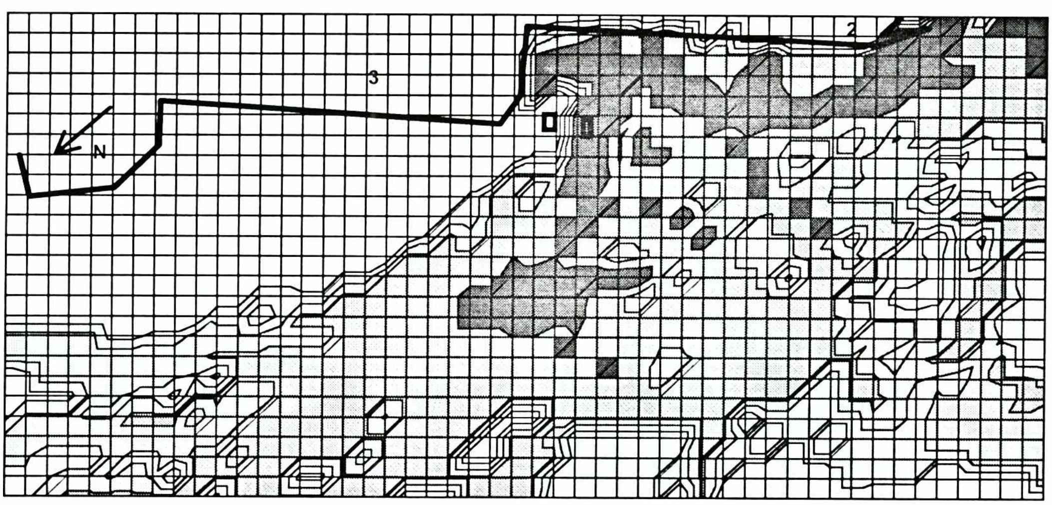


Fig. 4. Velocity distribution of maximum discharge current at the bottom of m/f „Polonia" at berth in Sea Ferry Terminal in Świnoujście

SHIP OPERATION & ECONOMY

Presently research tests are carried out aimed at designing a new entrance to the port of Kołobrzeg. One of the proposals of ship's manoeuvring region (ships of L_{oa} = 100 m) and all directions of wind of up to 10 m/s is presented in Fig.3.

OTHER CONDITIONS OF SAFE MANOEUVRING

Other conditions of safe manoeuvring not discussed here such as safe amount of water under keel, safe speed of discharge current, safe kinetic energy of ship's impact on the quay can be characterized as follows:

- Safe amount o water under keel is defined only by means of empirical methods regardless of the problem solved;

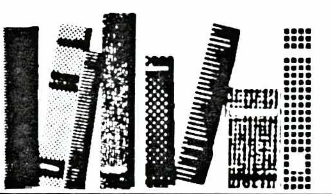
- The condition of safe speed of discharge current at the bottom is solved by means of empirical method in the case of an analysis of performing specific manoeuvre [6]. In the case of designing or modernizing waterways or designing the ships intended to operate in specific water regions this criterion can be met by using the computer simulation method;

- The problem of safe speed of discharge current is of particular significance while designing the ships of large propulsion power and with bow thrusters intended to manoeuvre in ports by themselves, e.g., sea ferries. A research on the problem was carried out in the Institute of Sea Navigation while designing the parameters of bottom strengthening of the Sea Ferry Terminal in Świnoujście [9]. Fig.4 presents the distribution of discharge currents from the manoeuvring of the „Polonia" ferry at berth no.2, obtained from simulation tests carried out in different hydrometeorological conditions (wind up to 15 m/s, current up to 1.5 knots);

- The criterion of safe kinetic energy of ship's impact on the quay refers only to the port waters in which a berthing manoeuvre takes place. Safe kinetic energy of the ship's impact on the quay is determined while designing or modernizing the quays (port basins, terminals) or in the case of change of their operating conditions. The energy is specified by means of empirical or simulation methods. The simulation methods are used for more complex waterways [4].

BIBLIOGRAPHY

1. „Analiza nawigacyjna Pomorskiego Terminalu Paliwowego w Świnoujściu. Badania symulacyjne ruchu statków określające wytyczne projektowe zabudowy portowej i warunki eksploatacyjne". Praca zbiorowa. Wyższa Szkoła Morska. Szczecin, 1993 (Int. publ. of Maritime University in Szczecin)
2. Gucma S.: „Application of Computer Simulation Methods of Ship Movements to Waterway Designing". 28-th International Navigation Congress. Seville, 1994
3. Gucma S.: „Metody wyznaczania i kształtowania dróg wodnych". Studia nr 15. Wyższa Szkoła Morska. Szczecin, 1990 (Int. publ. of Maritime University in Szczecin)
4. Gucma S.: „Obciążenia nabrzeży od cumujących statków. Dobór i rozmieszczenie urządzeń odbojowych". BPBM „Bimor". Szczecin, 1994 (Int. publ. of „Bimor")
5. Gucma S.: „Optymalizacja parametrów basenów portowych terminali wielofunkcyjnych." IX Konferencja naukowo-techniczna nt.: „Rola nawigacji w zabezpieczeniu działalności ludzkiej na morzu". Akademia Marynarki Wojennej. Gdynia, 1994
6. Gucma S., Jagniszczak I.: „Nawigacja dla kapitanów". Wyższa Szkoła Morska w Szczecinie (To be published)
7. Guziewicz J.: „Weryfikacja metody określania rozmiarów obszarów manewrowania statku opartej o rozkład normalny". IX Konferencja naukowo-techniczna nt.: „Rola nawigacji w zabezpieczeniu działalności ludzkiej na morzu." Akademia Marynarki Wojennej. Gdynia, 1994
8. „Navigational Analysis of Entrance and Port Manoeuvres in the Port of Ystad for a Newly Designed Universal Ferry (Ystadmaks)". Szczecin,1993 (Int. publ. Maritime University in Szczecin)
9. „Określanie i ocena rozkładu prędkości strumieni zaśrubowych przy dnie stanowisk Nr 2 i Nr 3 Bazy Promów Morskich w Świnoujściu określonych na podstawie badań symulacyjnych ruchu nowobudowanego promu m/f „Polonia" oraz promu m/f „Jan Śniadecki". Wyższa Szkoła Morska. Szczecin , 1994 (Int. publ. of Maritime University in Szczecin)



Conferences

SYMPOSIUM ON SHIP POWER PLANTS

XVIII International Symposium on Ship Power Plants was held in Gdynia Maritime Academy, Gdynia, on 17 and 18 October 1996.

For a dozen or so years such scientific symposia have been organized by the similar chairs of the Technical University of Gdańsk, Technical University of Szczecin, Gdynia Maritime Academy, Maritime University in Szczecin and Naval Academy in Gdynia, which educate specialists in the designing and operating of the ship power plants and carry out research in this area.

The Chairs are one by one the host of the yearly symposia and XVIII Symposium was arranged by that of Gdynia Maritime Academy.

The symposium was devoted to the memory of Prof. Kazimierz Chachulski, a distinguished teacher and expert in the field of ship power plant operation and optimization, who died in the last year.

126 participants took part in the XVIII Symposium, among which , apart from the authors of papers, were the representatives of more than ten shipyards, ship owners and the design and research centres cooperating with the shipbuilding industry. The number witnesses the high interest paid to the theme of the symposium.

Its proceedings were divided into the following six sessions:

- Teaching (5 papers)
- Designing (9 papers)
- Reliability, Safety and Ecology (6 papers)
- Operation (8 papers)
- Modelling (6 papers)
- Diagnostics (5 papers).

Altogether 40 papers were submitted to the symposium, inclusive of the inaugural lecture devoted to the life and scientific achievements of Prof. Chachulski. 28 of the papers were prepared by the authors from five Polish maritime universities, 2 by the authors from the Institute of Fluid Flow Machinery, Polish Academy of Sciences, and of the Polish Register of Shipping. Several papers were submitted by the authors from abroad: 7 from Russia, 2 from Ukraine and 1 from the Technical University of Hamburg.

The symposium was complemented by the opportunity to acquaint the participants with the interesting didactic stands of the Gdynia Maritime Academy: the ship power plant simulator and simulator for testing the reliability of the man - operator of the automatic ship power plant . Both the stands are computerized and effectively improve educating qualified operators of the ship power plant systems.

The symposium gave also the occasion to present the actual offer and current development trends of products of such known producers as: ZGODA, SULZER, WÄRTSILÄ and B&W (marine engines), WESTFALIA SEPARATORS and ALFA LAVAL (oil separators), WOODWARD GOVERNOR (engine controls), as well as SCHAELLER - AUTOMATION, Dr E. HORN and UNITEST (marine measurement and control equipment).

The Symposium proceedings were very neatly edited as a book (of 360 pages).