THE MODEL OF RISK DETERMINATION IN SEA- RIVER NAVIGATION

MODEL OCENY RYZYKA W ŹEGLUDZE MORSKO-RZECZNEJ

Wiesław Galor

Maritime University of Szczecin, Institute of Marine Traffic Engineering
Walny Chrobrego ½, 70-500 Szczecin, Poland
E-mail: (1) w.galor@am.szczecin.pl

Abstract: The process of navigation should be safely and efficiently. Navigation in inland waters is hard by the relation between the ship size and water area. The determination of safety of ship’s movement can be identified as a combination of probability of accident and losses. The overall risk of navigation ship can determined as the sum of these single risks depend on the under keel clearance, distance to navigational obstruction, air drought, collision with other floating craft and berthing energy. The paper presents method of the determination the safety of ship manoeuvring in sea-river navigation.

Keywords: safety of navigation, sea-river navigation, model of risk determination

Streszczenie: Proces nawigacji powinien być bezpieczny i efektywny. Nawigacja na wodach śródlądowych jest trudna, ze względu na relację pomiędzy wymiarami statku i akwenu. Określenie bezpieczeństwa ruchu statku może być określone ryzykiem, jako kombinacja prawdopodobieństwa wypadku i jego skutków. Całkowite ryzyko nawigacyjne statku może być określone, jako suma cząstkowych składowych związanych z ryzykiem związanym z zapasem wody pod stępką, odległością mijania przeszkód nawigacyjnych, wysokością przeszkód, koliżją z innymi statkami i energią cumowania. W artykule przedstawiono metodę określania bezpieczeństwa manewrowania statku w żegludze morsko-rzecznej

Słowa kluczowe: bezpieczeństwo nawigacji, żegluga morsko-rzeczna, model określania ryzyka
Introduction

The safety of navigation can be estimated by means of notions of safety navigation. It may be qualified as set of states of technical, organizational, operating and exploitation conditions and set of recommendations, rules and procedures, which when used and during leaderships of ship navigation minimize possibility of events, whose consequence may be loss of life or health, material losses in consequence of damages, or losses of ship, load, port structures or pollution of environment. Very often, the sea-river ships move on waterways (natural and artificial) inside of land for hundreds kilometres. The manoeuvring of ships on each water area is connected with the risk of accident, which is unwanted event in results of this can appear the losses. There is mainly caused by unwitting contact of ship’s hull with other objects being on this water area. The safety of ship’s movement can be identified as admissible risk, which in turn can be determined as combination of probability of accident and acceptable losses level. As a result, a navigational accident may occur as an unwanted event, ending in negative outcome, such as:

- loss of human life or health,
- loss or damage of the ship and cargo,
- environment pollution,
- damage of port’s structure;
- loss of potential profits due to the port blockage or its parts,
- coast of salvage operation,
- other losses.

The inland waterways are restricted areas those where ship motion is limited by area and ships traffic parameters. Restricted areas can be said to have the following features:

- restriction of at least one of the three dimensions characterizing the distance from the ship to other objects (depth, width and length of the area),
- restricted ship manoeuvring,
- the ship has no choice of a waterway,
- necessity of complying with safety regulations set for local conditions and other regulations.

Thus the navigation on such waterways is different than on approaching waterways and coastal water areas. The realization of navigation on limited water areas is consisted on:

- planning of safety manoeuvre,
- ship’s positioning with required accuracy on given area,
- steering of craft to obtain the safety planned of manoeuvre.
Ship handling is first and foremost supposed to be safe so that will not bring about a navigational accident, which is an unwanted event resulting in losses. The losses may be different kinds like a loss of human health or life, damage or loss of cargo and ship, the pollution on environment, damage to a port structure or financial losses due to the port or its part being blocked.

- The safety level is most often determined by risk measure. There are many ways of risk to be defined. Generally risk is identified with possible effect (losses) of an unwanted event (accident).
- A more exact definition says that it is the probability of losses due to accident, which may arise in a particular part of the man-technique-environment system.
- In practice it means the necessity of mailing conception of risk reduction measures and calculation the risk reduction achieved and the associated value of losses [1].
- The risk concept used to be defined in different of way. Mainly the risk referred to as navigational risk may be expressed as:

\[ R_N = P_A \cdot C \]  

where:
- \( R_N \) navigational risk,
- \( P_A \) frequency of accident,
- \( C \) consequence of accident in relevant units (losses).

1. The determination of safety navigation

To assessment and analyse the safety, especially in the quantitative manes, the necessary to select values that can by treaded as a safety measures. It permits to determine the safety level by admissible risk [3]:

\[ R_a = P_A \left[ d(t)_{max} < d_{min} (0 < t < T_p) \right] \text{ for } c < C_{min} \]  

where:
- \( d(t)_{max} \) - distance of craft hull to other objects during manoeuvring,
- \( d_{min} \) - least admissible distance of craft hull to other objects,
- \( T_p \) - time of ships manoeuvring,
- \( c \) - losses as result of collision with object,
- \( C_{min} \) - the acceptable level of losses.

Because the losses can be result different events [8], the following criterion of safety assessment will be used:

1. Safety under keel clearance (SUKC)
2. Safety distance to structure (SDS)
3. Safety distance of approach (SDA)
4. Safety air drought (SAD)
5. Safety of berthing (SOB)

Thus, there are many categories of risk due to ship movement in water area. In each case the accident rate (probability) is determined for each of the accident categories. The overall risk of ship movement in water area in then the sum of these single, independents risks [5]:

\[ R_o = R_g + R_n + R_c + R_{ad} + R_b \]  

(3)

where:
\( R_o \) - overall risk of ship movement in water area,
\( R_g \) - risk of grounding,
\( R_n \) - risk of collision with navigations obstructers,
\( R_c \) - risk of collision with other ships and
\( R_{ad} \) - risk of impact the object over the ship,
\( R_b \) - safety of berthing.

2. Safety under keel clearance (SUUKCT)

The underkeel clearance is a vertical distance between the deepest underwater point of the ship’s hull and the water area bottom or ground. That clearance should be sufficient to allow ship’s floatability in most unfavourable hydrological and meteorological conditions. Consequently:

\[ H \geq T + R_B \]  

(4)

where:
\( H \) – depth,
\( T \) – ship’s draft and
\( R_B \) – safe underkeel clearance (UKC).

The safe underkeel clearance should enable the ship to manoeuvre within an area so that no damage to the hull occurs that might happen due to the hull impact on the ground. A risk of an accident exists when the under keel clearance is insufficient [3]. When determining the optimized UKC we have to reconcile contradictory interests of maritime administration and port authorities. The former is responsible for the safety of navigation, so it wants UKC to be as large as possible. The latter, wishes to handle ships as large as possible, therefore they prefer to accept ships drawing to the maximum, in other words, with the minimized UKC. The maximum UKC requirement entails restricted use of the capacity of some ships, which is ineffective in terms of costs for ports and ship operators. In the extreme cases, certain ships will resign from the services of a given port. Therefore, the UKC optimization in some ports will be of advantage. It is possible if
the right methods are applied. Their analysis leads to a conclusion that the best applicable methods for UKC optimization are the coefficient method and the method of components sum. In the coefficient method one has to define the value $R_{\text{min}}$ as part of the ship’s draft:

$$R_{\text{min}} = \eta T_c$$

where:
- $\eta$ = coefficient and
- $T_c$ = deepest draft of the hull.

The applied coefficient $\eta$ values range from 0.04 to 0.4 [6]. The other method consists in the determination of $R_{\text{min}}$ as the algebraic sum of component reserves [6] which accounts for errors of each component determination:

$$R_{\text{min}} = \sum R_i + \delta_r$$

where:
- $R_i$ = depth component reserves and
- $\delta_r$ = sum of errors of components determination.

The UKC is assumed to have the static and dynamic component. This is due to the dynamic changes of particular reserves. The static component encompasses corrections that change little in time. This refers to a ship lying in calm waters, not proceeding. The dynamic component includes the reserve for ship’s squatting in motion and the wave impact. One should emphasize that with this division the dynamic component should also account for the reserve for ship’s heel while altering course (turning).

3. **Safety distance to structure (SDS)**

The accessible port water area (for given depth) warrants safety manoeuvring for fulfill condition [1]:

$$\omega \in \Omega$$

where:
- $\omega$ - requisite area of ship’s manoeuvring
- $\Omega$ - accessible water area.

Ships contact with structure can be intentional or not. Intentional contact steps out when ship berthing to quay. During this contact energy dependent
from virtual ship masses and its perpendicular component speed to the wharf is emitted. In result of ship pressure on wharf comes into being reaction force. Both emitted energy during berthing and bulk reaction force cannot exceed admissible value, definite by reliability of ship and wharfs. These values can be decreased by means of fenders, being usually of wharf equipment. Ship should manoeuvre in such kind to not exceed of admissible energy of fender-structure system. Unintentional contact can cause navigational accident. Process of ship movement in limited water area relies by suitable manoeuvring. During of ship manoeuvring it can happen the navigational accident. Same events can occur strike in structures, when depth of water area is greater than draught ship. There are usually structures like wharf, breakwater, locks, bridges (in width of them-fig.1), etc., and also floated objects moored to structure.

4. Safety distance of approach (SDA)

The fundamental measure of ships passing is distance to closest point of approach (DCPA). Its value should be safety, it means:

\[ DCPA \geq DCPA_{\text{min}} \quad (8) \]

where:
- \( DCPA \) - distance to closest point of approach
- \( DCPA_{\text{min}} \) - acceptable distance to closest point of approach.

![Fig.1 Railway bridge in Podjuchy – Szczecin](image)
5. Safety of air drought (SAD)

Air drought is distance over ship, when manoeuvre under construction. They mainly consist:
- bridges (road, railway) over waterway (fig.2),
- high voltage lines,
- pipelines over waterway,

The condition of safety ship movement is following:

$$H_S < H_C$$  \hfill (9)$$

where:
- $H_S =$ the height of highest point of ship
- $H_C =$ the height of lowest point of construction over waterway

In many cases, the sea-river ship’s superstructure is regulated. It permits to decrease of ships height. Also other elements of ship’s construction can be disassembled – for instance masts of radar antenna, radio etc.

Fig. 2. The bridge in Gryfino.
Safety of berthing (SOB)

Condition of the safety of the manoeuvre while berthing the ship to the quay can be as follows [4]:

\[ E(t) \leq E_{k}^{\text{berth}} \text{ or } E(t) \leq E_{k}^{\text{ship}} \]  

(10)

where:

- \( E(t) \) - maximum kinetic energy of the ship's impact absorbed by the system berth - fender – ship,
- \( E_{k}^{\text{berth}} \) - admissible kinetic energy absorbed by the system berth - fender,
- \( E_{k}^{\text{ship}} \) - admissible kinetic energy, near which the formed strengths of the reaction of the em system berth – fender do not cause the durable deformation of the ship's hull yet.

Factors which have the influence on the size of the maximum kinetic energy of the ship’s impact against the berth construction (fig. 3) are as follows:

*Fig. 3. The berthing of ship to the quay (Międzyzdroje Pier)*
Conclusions

The sea-river ships move on waterways (natural and artificial) inside of land in many cases for hundreds kilometres. The ship can came natural objects (coast, water bottom) and artificial (water port structures-locks, bridges etc.) obstructers. Also many other ships can encounter. It caused that the navigation in inland waters is harder than on open seas. The criterions of safety assessment of ship movement need more precisely of qualify. The risk can be used as measure of safety. This risk is a sum of independent components connected with different possibilities of potential accidents. They are a result of unwanted contact with objects on inland water area. The presented above consideration can permit to analysis of safety sea-river ships in inland shipping.

The following components to determine the overall risk can be taken into account:
- safety under keel clearance (SUKC),
- safety distance to structure (SDS),
- safety distance of approach (SDA),
- safety air drought (SAD),
- safety of berthing (SOB).

The above presented considerations in the paper can permit to analysis of safety ships in limited waters by quantity measurement manner. As results, it is possible achieved effective effects by using of ones to practically managing of safety of maneuvering ship in limited waters, as optimize process of such navigation.

References


Prof. DSc. Eng. Deck Off. GALOR Wiesław, Professor at Institute of Marine Traffic Engineering, Faculty of Navigation, Maritime University of Szczecin, Poland. Specialization: safety of navigation, marine traffic engineering, safety of ship manoeuvring in limited water area, designing of fender systems. Membership in many scientific committees of conferences and congresses. Many publications in field.