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The Criterion of Safety Navigation Assessment in Sea-River Shipping

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ABSTRACT: Sea–river ships can connect the area inside of land with oversea places without of indirect trans- shipment. In many cases the sea-river ships move on waterways (natural and artificial) inside of land for hundreds kilometres. Navigation in inland waters has to meet the same requirements as those for pilot navigation. This is due to the relations between the ship size and other objects on water area. These ones caused the navigation more hard then on open seas. The paper presents the criterion of safety assessment of navigation during sea-river ships manoeuvring ship in inland waters.

1 INTRODUCTION

Process of ships movement in water area should be safely. Its estimation is executed by means of notions of safety navigation. It may be qualified (Galor W. 2001) 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 ships 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:

$$R_{adm}=P\ C_{min} \quad (1)$$

where: R_{adm} = admissible risk, P_A = probability of accident and C_{min} = 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.

In a few cases, especially for ports situated inside of land, there are the waterways and canals with great lengths of hundreds kilometres. 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 (Galor W. 2005):

- planning of safety manoeuvre,
- ship's positioning with required accuracy on given area,
- steering of craft to obtain the safety planned of manoeuvre,
- avoiding of collision with other ships.

Approach channels to port and port water area are characterised by occurrence of port structures. These constructions are result of activity of man and embrace aquatic or under-water structure which together with installations, builder's devices connected with them and other advisable necessary equipment to realize of its intended function to state whole of technical using. From sight of view limitation of movement in water area, ports structures envelop following component:

- objects arising in result of executing of dredged works such port and shipyard water, especially and basin, sea and lagoon fairways, approach channels, turning basins,
- channels,
- wharfs determining of water area coast and largely making possible berthing to them and mooring of ships,
- constructions of coast protection such breakwaters, under-water thresholds, strengthening of bottom, scarp of fairways deepened,
- constructions of fixed navigational marks such lighthouses, situated on shore of sea water area and aquatic, light lines and navigational marks, navigational dolphins,
- locks (fig.1),

Figure 1. The lock in Czyżykówko on Wisła – Odra waterway

- structures situated in area of sea harbour, in particular isles of berthing and trans-shipment, shipping foot-bridges,
- port structures, situated in area of sea harbour in particular breakwaters, breakers of waves, wharfs trans-shipment and berthing and other,
- structures connected with communication, in particular road – bridges, railway, submarine tunnels,
- structures connected with exploitation of sea bottom (drilling towers, platforms, submarine pipelines).

Besides to number to them it is necessary: constructions of floating navigational marks, in particular anchored navigational buoys.

2 THE CRITERION OF SHIPS SAFETY ASSESSMENT

The restricted area is characterized by a great number of factors being present at the some time. It caused that possibility of navigational accident in these areas is more then in other ones. It means the navigation safety is lower in restricted areas. The assessing of navigation safety requires the application of proper criteria, measures and factors. The criteria make it possible to estimate the probability of navigational accident for certain conditions. The ship during process of navigation has to implement the following safety shipping conditions:

- keeping the under keel clearance,
- keeping the proper distance to navigational obstruction,
- keeping the proper air drought,
- avoid of collision with other floating craft,

To determine 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 (Galor W. 2001a):

$$R_a = P_A[\, d(t)_{max} < d_{min}\ (0< t <T_p)]\ for\ c <C_{mi} \tag{2}$$

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 and C_{min} = the acceptable level of losses.

Because the losses can be result different events, 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)

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:

$$R_o = R_g + R_n + R_c + R_{ad} \tag{3}$$

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.

3 SAFETY UNDER KEEL CLEARANCE (SUKC)

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:

$$H \geq T + R_B \tag{4}$$

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. 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_{min} as part of the ship's draft:

$$R_{min} = \eta \; T_c \tag{5}$$

where: η = coefficient and T_c = deepest draft of the hull. The applied coefficient η values range from 0.04 to 0.4 (Mazurkiewicz B. 2008). The other method consists in the determination of R_{min} as the algebraic sum of component reserves [6] which accounts for errors of each component determination:

$$R_{min} = \sum R_i + \delta_r \tag{6}$$

where: R_i = depth component reserves and δ_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).

4 SAFETY DISTANCE TO STRUCTURE (SDS)

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

$$\omega \in \Omega \tag{7}$$

where: ω = requisite area of ship's manoeuvring and Ω = accessible water area.

Ships contact with structure can be intentional or not. Intentional contact steps out when ship berthing to wharf. 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, etc., and also floated objects moored to structure.

5 SAFETY DISTANCE OF APPROACH (SDA)

Where:

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

$$DCPA \geq DCPA_{min} \tag{8}$$

where: $DCPA$ = distance to closest point of approach and $DCPA_{min}$ = acceptable distance to closest point of approach.

The accident can happen; when above condition will not be performance. Knowing the number of entries of ships in a year (annual intensity of traffic), one can determine the probability of ships collision for one ship transit:

$$p_A = \lambda / I_R \cdot t \tag{9}$$

where: p_A = probability of ships collision in one transit, λ = accident frequency, I_R = annual traffic intensity and t = given period.

Determinate the probability of accident for given number of ship transits it can used the following formula (Galor W. 2004):

$$P_{A(N)} = N \cdot p_A = I \cdot T \cdot p_A \tag{10}$$

where: $P_{A(N)}$ = probability of accident for given ship transit number and N = number ship of transits.

This relationship is linear because implies proportional growth of probability to considered of ship number transit. More adequate manner is use the statistical models described the accident probability. Because accidents are infrequent events thus it can be used recurrent models. One of them is geometrical distribution:

$$P_{A(N)} = 1 - (1 - p_A)^N \qquad (11)$$

Figure 2 presents the probability of navigation accident for linear and geometrical distributions in function of ships transit numbers.

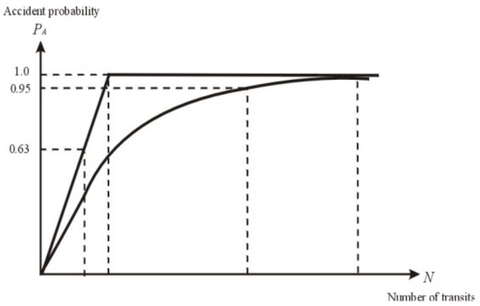

Figure 2. Probability of accident in function of transits number for linear and geometrical distributions

It results that for given value of accident probability (for example 0.95) for linear distribution it is achieved up to about three times less than for geometrical distribution.

6 SAFETY AIR DROUGHT (SAD)

Air drought is distance over ship, when manoeuvre under construction. They mainly consist:

- bridges (road, railway) over waterway (fig.3),
- high voltage lines,
- pipelines over waterway,

The condition of safety ship movement is following:

$$H_S < H_C \qquad (12)$$

where: H_S =the height of highest point of ship and 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.

Figure 3. The road bridge over Noteć river in Santok (Poland)-(Nadolny G. 2005)

7 CONCLUSION

The sea-river ships move on waterways (natural and artificial) inside of land in many cases for hundreds kilometres. The ship can pass natural objects (coast, water bottom) and artificial objects (water port structures-locks, bridges etc.). Also many other ships can manoeuvre on area. 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.

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