THE ROLE OF NAVIGATIONAL RISK ASSESSMENT DURING SHIP'S MANOEUVRING IN LIMITED WATERS

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Abstract

The main purpose of navigation is a safe and efficient leading of the ship between various points. This process should be safely and efficiently. The process of safe movement of the ship in the area is called safe navigation. These areas are called as limited waters. 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. Among water areas there are those where ship manoeuvring is restricted more than in other sea areas. These areas are called as limited waters. They are mainly characterised a relatively high number of navigation accidents. 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 safety of ship's movement can be identified as admissible risk, as a combination of probability of accident and losses. The overall risk of ship movement in water area in then the sum of these single risks depehd on the under keel clearance, distance to navigational obstruction, air drought, collision with other floating craft and berthing energy.Such way permits to assess of safety of ship's manoeuvring by quantity. The paper present the method of risk assessment for ship's in limited waters by analysis of basic elements restricted its movement.

Keywords:transport, navigational risk, limited waters, ship's manoeuvring

1. Introduction

The main goal of navigation is to handle the ship in accordance with aim of their movement when required parameters of this process should be retained. Realisation of this goal depends on assurance of suitable level of ships safety during their manoeuvring in water area. It should be evident acknowledged that almost all human activities involve risk. Accepting the thesis of "zero risk" into consideration is a mistakenly. Many branches of human activity can bring about different kinds of risk. The marine environment is one where risk is greater than the average. It refers chiefly to shipping activities which main purpose is to provide services by merchant ship involved in trading. It is fulfilled by handling the ship to port of destination in safely manner. Among water areas there are those where ship manoeuvring is limited more than in other sea areas. These areas are called as limited waters. They are mainly characterised a relatively high number of navigation accidents [4]. There are many definition and names of such type of waters. The universal definition of limited waters may be that it is area, where the ship can't choose the free way. This limitation is caused by factors that affect the ship manoeuvring. The ship, however, may be affected by various factors during that process, which sometimes make it difficult. This means that in certain conditions just any trajectory cannot be planned for the ship, and on the other hand, steering the traffic on a properly planned trajectory is not always possible. An important element of the ship's environment is a limited water area where the ship moves. This purpose is put into practice by steering the ship movement on a planned trajectory. The occurrence of factors affecting the ship's movement causes its free way limitation. As the ship's leading should be safe first of all, which means it should not cause any navigational accident.

A navigational accident is an undesirable occurrence which can cause different loss. Mainly there are life or health, loss or damage to ship or cargo, the pollution of natural environment, damage to the port structure, economical loss due to blocking of the port or its part, cost of salvage operation and other [2].

The process of safe manoeuvring of the ship in the area is called safe navigation. Its estimation is measured by the safety of navigation. It may be defined as a set of states and technical, organizational, operational and working conditions and also as a set of orders, regulations and procedures the applications of which and complying with brings down to minimum the probability of undesirable events that can cause losses [9].

2. The limited waters

One of definition of limited waters, peaceable from IMO (International Maritime Organisation) [1] this is one with water area about depth to 40 m and distances to nearest navigational obstruction less than 3 Mm. There are straits, outlets of rivers, channels, water area port and water area about comparatively small area and depths. They are characterised first of all:

- limited possibilities of manoeuvring,
- necessity of manoeuvring in according with planned tracks at definite trajectory, with participation of pilot or individually,
- necessity of adaptation of movement to local rules,
- occurrence of navigational natural obstructions (shallows, reefs and other) or artificial (wrecks, mine fields).

Generally this can describes that the limited waters is one on which occur factors decreasing possibility free choice of way by ship.

There are following factors:

- geometrical dimensions of water area (width, depth) and its shape and connected at this occurrences,
- port structures (locks, wharfs, marking navigational-fixed and floating),
- hydro meteorological conditions (currents, tides, unprofitable directions of wind, ice),
- traffic vessels restrictive accessible water area of navigating or caused suitable manoeuvring,
- large number of other craft like as barges, bunkers, fishing boats, ferries of local service, that generally are subjected to vessels traffic, but in certain situations can make difficult manoeuvring of sea – going ships,
- navigation obstacles like as ships on anchor, moored ships, docks, dredgers, hydrographical ships busy at marking navigational,
- operations with modernisation, reconstruction or build of new construction that restrictive movement of ships,
- accessible systems of ship position estimation with required accuracy,
- vessels traffic system,
- rules (international and local) putting into ships trajectory of movement.

Generally in limited water areas number of these factors appearing simultaneously is great. It caused growth possibility of accuracy of navigational accident. Then even single factor of set can contribute to considerable of decreasing safety level. One kind of limited waters are port waters area. There are area surrounded by wharfs or other port structures, at of which takes place berthing and trans-shipment of ships. This type of water area for manoeuvring ships has special importance for port operation. As a rule, a limited waters feature a great number of these factors being present at the some time. It caused the possibility of navigational accident in these areas is more many times then in other ones. It means the navigation safety is lower in limited waters.

3. The measure of safety navigation

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 [3].

The risk concept used to be defined in different of way. Mainly the risk referred to as navigational risk may be expressed as:

$$R_N = P_A \cdot C, \tag{1}$$

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

As it has already been mentioned, a picture of the situation closer to completeness is presented by navigational risk. Knowing the probability of the accident, its effects can be taken into account in the calculations. When applying the risk, three methods can be distinguished [2]:

- the value of absolute risk;
- risk constant;
- relative increase of risk.

In the first method the determined risk value refers to the assumed value limit. Sometimes this value is specified in regulations.

$$R_N \le R_p, \tag{2}$$

where:
R_N - determined risk value,
R_p - assumed risk value limit.

The next method of constant risk is a development of the first. It is applied in situations where the effects of the accident are likely to change. This can take place when a ship of a specified size manoeuvring on a certain water area is carrying in turn cargoes of various hazard degrees (various effects in case of accident, e.g. coal, and the other time crude oil products). Then, to maintain a steady level of safety, the risks must be equal to each other.

$$R_{N1} = R_{N2} = P_{A1} \cdot C_1 = P_{A2} \cdot C_2, \tag{3}$$

where:
R_{N1}, R_{N2} - navigational risk,
P_{A1}, C_1 - probability of an accident and consequences of the accident with cargo of low hazard degree,
P_{A2}, C_2 - probability and consequences of an accident with cargo of higher hazard degree.

Taking into consideration that the risk is a combination of accident probability and its consequences, the following can be written:

$$\rho R = \rho P_A + \rho S, \tag{4}$$

where:
ρP_A - relative increase of accident probability,
ρS - relative increase of accident consequences.

4. The criterion of ships safety assessment

The limited 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 than in other ones. It means the navigation safety is lower in limited 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,
- keeping the proper of berthing energy.

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 [6]:

$$R_a = P_A [\, d(t)_{max} < d_{min} \, (0< t <T_p)] \; for \; c <C_{min} \tag{5}$$

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} - 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:

$$R_o = R_g + R_n + R_c + R_{ad} + R_b, \tag{6}$$

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,
R_{ad} - risk of impact the object over the ship,
Rb- safety of berthing.

4.1. 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:

$$H \geq T + R_B, \tag{7}$$

where:
H - depth,
T - ship's draft,
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 [5]. 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:

$$R_{min} = \eta\ T_c, \tag{8}$$

where: η = coefficient and T_c = deepest draft of the hull. The applied coefficient η values range from 0.04 to 0.4 [10]. 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:

$$R_{min} = \sum R_i + \delta_r, \tag{9}$$

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).

4.2. Safety distance to structure (SDS)

The accessible port water area (for given depth) warrants safety manoeuvring for fulfill condition [2]:

$$\omega \in \Omega, \tag{10}$$

where:
ω - requisite area of ship's manoeuvring,
Ω - 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 (Fig. 1), etc., and also floated objects moored to structure.

Fig. 1. The ship in the lock (Czyżykówko Lock)

4.3. 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:

$$DCPA \geq DCPA_{min}, \tag{11}$$

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

4.4. 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:

$$H_S < H_C, \tag{12}$$

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


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Fig. 2. The railway bridge (Podjuchy- Szczecin)

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.

4.5. Safety of berthing (SOB)

Condition of the safety of the maneuver while berthing the ship to the quay can be as follows [7]:

$$E(t) \le E_k^{berth} \text{ or } E(t) \le E_k^{ship}, \tag{13}$$

where:

E(t) - maximum kinetic energy of the ships impact absorbed by the system berth - fender – ship,
E_k^{berth} - admissible kinetic energy absorbed by the system berth - fender,
E_k^{ship} - admissible kinetic energy, near which the formed strengths of the reaction of the system berth – fender do not cause the durable deformation of the ships 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)

- ship manoeuvrability (kind and the power of the propulsion, thrusters),
- hydrometeorological conditions (wind, current),
- tugs service (the number of tugboats, their power),
- the manoeuvring tactics (captain's or pilot's skill).

5. Conclusions

Limited area as such area used to ship navigation is characterised by existing of elements increasing free choice possibility of way by ship. It causing that realisation of basic navigation aim, which is safety and efficiency ship operating, can be difficult or sometimes impossible. 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 limited 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 water area. The follwing components to determine the overall risk were 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 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.

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