<< Powrót do spisu artykułów

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COMPREHENSIVE SAFETY ANALYSIS OF SHIP - PORT SYSTEM WITH RESPECT TO FERRY MANOEUVRING OPERATIONS

Abstract: The paper presents the safety analysis of ship-port system with respect to manoeuvring operations of ro-pax ferries. The complex character of the analysis is related to the wide spectrum of external hazards concerning harbour manoeuvres in different hydrometeorological conditions and modelling of ship performance in the ship-port system. The manoeuvres critical from the interactions in ship-port system point of view are investigated: navigation along the approach channel, berthing and unberthing operations.
Keywords: safety analysis, port manoeuvring operations, ro-pax ferry navigation

1. INTRODUCTION

The functioning safety management systems in ports differ from each other according to the port organisation structure and competence sharing between the port authority, maritime administration and port institutions. The most complex integrated port safety management systems involve the whole range of port activities.

The system approach in safety management in ports is generally accepted however there are many doubts of the superficial nature of the systems and unknown level of uncertainties in the risk assessment procedures [1].

In most cases safety of manoeuvring operations in ports is directly related to the value of acceptable risk [2], [3]. The basic method used to identify the risk of manoeuvring operations in ports is HAZID - HAZard IDentification - well-organised meeting of the multidisciplinary team of experts, personnel, process safety engineers. The information about hazards, their causes and consequences is collected and processed. Despite of this review method the analytical approach is applied. The methods most frequently used for the assessment of hazards are the risk matrix, Event Tree Analysis (ETA) and Fault Tree Analysis (FTA).

The majority of accidents reported in ship – port interface is due to human factor in relation with the manoeuvring procedures.

The causes of the accidents in most investigated cases have been concluded as the lack of adequate monitoring of the vessel's position, poor communication on the bridge, poor passage planning with respect to pilotage, absence of positive traffic control, lack of the proper manoeuvring procedures or their violation.

Safety analysis involves all possible hazards, their causes, consequences and risk reduction measures. To evaluate the magnitude of hazards and consequences the experienced judgement and quantitative models are considered. All consequence categories are investigated: health, public disruption, environmental impact, financial impact, public and media attention.

Intolerably high risk can be reduced to a tolerable level assumed as ALARP (As Low as Reasonably Practicable) by both improving prevention (reducing probability) and improving mitigation (reducing consequence).

The safety analysis of ship-port system with respect to manoeuvring operations of ro-pax ferries can be much detailed than the general analysis of ship-port system due to the possibility of obtaining close models and available online data.

The complex character of the analysis presented in the paper is related to the wide spectrum of external hazards concerning harbour manoeuvres in different hydrometeorological conditions and modelling of ship performance in the ship-port system. From the interactions in ship-port system point of view the navigation along the approach channel and berthing / unberthing are the critical manoeuvring operations. They are investigated with respect do determine safety measures applicable for a port safety management system.

2. QUANTITATIVE RISK ASSESSMENT OF SHIP MANOEUVRING

Formal Safety Assessment (FSA) introduced in 1997 into the ship-safety field by the IMO [4] applies broad principles of quantitative risk assessment (QRA) in the five-step procedure.

Since 1997 FSA has proved to be a method widely applicable, detailed in statistical analysis and effective in assessment, featuring by formal operational procedures, serial standard analysis techniques and decision making based on cost-benefit assessment.

The main options of safety assessment provided by FSA are the three, four and five-step methods. Along with FSA method the different risks models can be applied. In the traditional approach the magnitude of the risk is a function of both the probability that the event will occur and its consequences (Table 1 and 2).

Table 1

Consequence matrix – severity criteria for ship navigation

Consequences		People –injury	Property, Environment, Port
0	Insignificant	minor	<10,000 $
1	Minor	single slight	10,000 – 100,000 $
2	Moderate	multiple minor or single major	100,000 – 1,000,000 $
3	Major	multiple major or single fatality	1,000,000 – 10,000,000 $
4	Catastrophic	multiple fatalities	10,000,000-100,000,000 $

The risk matrix allows obtaining the risk scores which can be: negligible risk, low risk, ALARP, heightened risk, significant risk, high risk. The risk can be tolerated if the risk mitigation measures provide risk reduction into the ALARP region without the disproportionate costs.

Table 2

Frequency matrix

Frequency		Operational interpretation
1	Frequent	1/week – 1/year
2	Likely	1/year – 1/9 years
3	Possible	1/10 years – 1/99 years
4	Unlikely	1/100 – 1/999 years
5	Rare	< 1/1000 years

The alternative solutions may be used as for example relative risk model based on fuzzy functions and homogeneous Poisson process describing the time for the occurrence of the maritime accidents developed for Shanghai International Port [5].

In the case of manoeuvring within the port area the most effective risk control measure which has already enhanced safety in the dense areas is traffic control and management performed by VTS or Harbour Master's Office. Further improvement of safety is possible mainly by reducing the human factor contribution in the incidents. The most effective tools to reduce the human factor influence on safety can be the automatic navigation systems, still not available and decision support systems (DSS) [6].

The reduction of human factor in case of ferry operation is also important due to the very small time redundancy in the system, following from the specific character of short sea shipping.

To develop the DSS as a reliable risk reduction measure the comprehensive safety analysis must be applied. The decision support system (DSS) for ferry manoeuvring operations [6] can be proposed as a risk-based tool identifying and formulating hazards, estimating their probability, assuming the consequences and advising safe manoeuvring strategy for use by both the ship and traffic control. The detailed hazards identification for the particular ro-pax vessel and the direct analytical approach in the development of procedures used in risk assessment can be applied.

3. COMPREHENSIVE SAFETY ANALYSIS OF SHIP - PORT SYSTEM

The comprehensive safety analysis of ship–port system is based on the procedures developed for computing the online information of the possible hazards. It is related to the determination of the boundary values of operational parameters of ship-port system. The procedures are based on real and predicted ship performance.

The sources of the data for the comprehensive safety analysis of ship–port system with respect to ferry manoeuvring operation are as follows:

- traffic control,
- environmental conditions monitoring,
- environmental conditions modelling,
- ship motion identification,
- ship motion modelling,
- risk modelling.

The following internal and external hazards are analysed.

External hazards:

- hydrometeorological conditions (wind, current, waves):
  - improper ship-berth interaction during berthing,
  - improper ship performance during the navigation along the approach channel:
    - drift,
    - course
    - position along the approach channel,
- traffic:
  - non-standard initial position,
  - non-standard speed.

The internal hazards:

- human factor,
- technical failures.

The internal hazards have the direct influence on ship performance. The external hazards identified with respect to vessel traffic and hydrometeorological conditions are identified on the basis of ship performance models.

Most of the hazards can be modelled following formulations used in structural reliability or seakeeping analyses with a limit state function of basic variables g(**X**) [7]. The formulation of the g-function is determined by the nature of the hazard.

The system remains safe when g(**X**) function is positive, the hazard occurs when it is negative. $X=(X_1,X_2,\ldots,X_n)$ is a vector of basic random variables. The basic problem is reduced to the problem of calculating the small probability that:

$$g(X_1, X_2, \ldots, X_n) < 0 \qquad (1)$$

The value of g-function is a random variable. The variables describe functional relationships in the physical model as well as the randomness in the modelling. In simple cases the g-function can be reduced to some explicit analytical formula [7]. In practical cases when navigation along the approach channel or ship berthing are addressed the g-functions should be obtained from numerical calculations.

The most important is qualitative and quantitative recognition of physical phenomena arising during ship crabbing in the closed proximity to the quay and during her movement along the quay, in shallow water conditions, under the influence of wind and waves.

For the ship navigating along the approach channel the event of crossing the navigational boundaries (2) as proposed by Vorobiov [8] can be expressed as a stochastic measure (3) based on ship motion parameters $X_i(t)$ which are the components of vector Markov process.

$$\frac{B_n}{2L} - (0.5 - \bar{x}_f)|\psi| + |\eta| + \frac{B}{2L} \leq 0 \tag{2}$$

$$\frac{B_n}{2L} - (0.5 - \bar{x}_f)|X_{13}(t)| + |X_{15}(t)| + \frac{B}{2L} \leq 0 \tag{3}$$

Where B_n is the width of the approach channel, L, B, x_f – ship length, breadth and longitudinal centre of floatation accordingly, η and are $X_{15}(t)$ ship sway, ψ and $X_{13}(t)$ are ship yaw. The proposed threshold value $B_n/2L$ is assumed for the constant width of the approach channel.

3.1. Models used in the hazard identification process

The models used in the hazard identification process are as follows:

Navigation along the approach channel:

- wind, wave and current transfer functions for surge, sway and yaw,
- stochastic model of ship motion,
- stochastic model of crossing the navigational limits of approach channel.

Ship-berth interaction during berthing:

- ship motion model of ship movement along the quay and crabbing including ship-berth interaction,
- model of thrust streams generated by ship propellers and thrusters during berthing and unberthing,
- model of berthing energy.

When the small rudder angles, small yaw and drift angles are assumed the stochastic model of ship motion under wind and waves proposed by Vorobiov [8] can be used. Model tests and CFD calculations can be used to predict transfer functions for wave, wind and current forces generated on the hull.

Ship-berth interaction model is mainly based on model test results. The completed model of interaction forces is formulated on the basis of a sequence of the sub-models in dependence on the character of variation of the measured values in the particular ranges of influencing parameters. In this case a global model is combined with a sequence of partially overlapping sub-models, unrelated to each another and constrained. The simple linear superposition of the component forces induced by the propellers and bow thrusters acting separately can be applied only for deep water conditions [9].

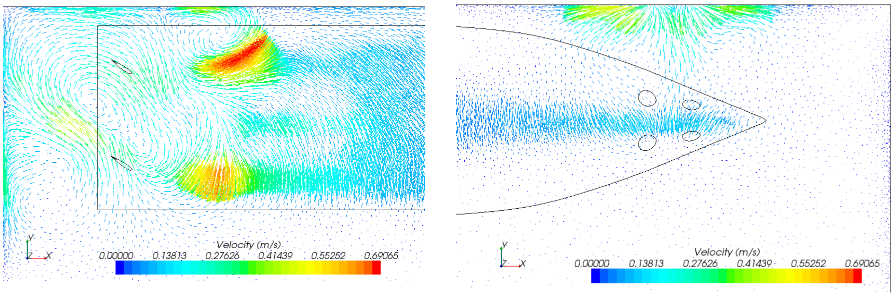

Fig. 1. Velocity distribution of the flow generated during unberthing on the sea bottom. Distance from the berth 0.1 ship breath, shallow water conditions

Model of the reliability of berth and sea bottom protection in the berthing area is based on the predicted influence of the thrust streams generated by propellers and thrusters during berthing and unberthing. The predicted flow field during unberthing, computed using CFD methods is presented in Figure 1.

The uncertainty of the ship performance prediction is related to the method this can be determined with. The results of model tests always include uncertainties due to scale effects and subjective assessment during tests evaluation. The computation using numerical methods also can be performed mainly in model scale. Therefore to have a proper validation of the model the real scale investigations are necessary.

4. CONCLUSIONS

The improvement of safety and performance indicators of Short Sea Shipping can be obtained through the improvement of safety and efficiency of ship manoeuvring operations. The improvement of safety is mainly connected with the reduction of human factor contribution in incidents. The solution for the human factor reduction is the application of risk-based DSS for ferry manoeuvring operations, based on the online information, and direct hazards modelling. The prediction of ship-port system performance is vital for the development of DSS. From the cost point of view, the development of decision support system is much more expensive than the reduced working hours and the increased training of personnel, but has much higher benefits in terms of time savings.

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KOMPLEKSOWA ANALIZA BEZPIECZEŃSTWA SYSTEMU STATEK - PORT W ASPEKCIE OPERACJI MANEWROWYCH PROMÓW

Streszczenie: W artykule przedstawiono analizę bezpieczeństwa systemu statek-port w odniesieniu do operacji manewrowych promów typu ro-pax. Kompleksowy charakter analizy związany jest z szerokim spektrum zagadnień związanych z zagrożeniami zewnętrznymi systemu podczas manewrów portowych w zmiennych warunkach hydrometeorologicznych oraz modelowaniem zachowania się statku, jako elementu systemu statek-port. Rozpatrywane są manewry krytyczne z punktu widzenia oddziaływania elementów systemu statek-port: żegluga na torze podejściowym oraz podchodzenie i odchodzenia od nabrzeża.

Słowa kluczowe: analiza bezpieczeństwa, manewry portowe, żegluga promowa