RELIABILITY IN MARITIME TRANSPORT

NIEZAWODNOŚĆ W TRANSPORCIE MORSKIM

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Abstract: *The paper presents the vessel reliability while realizing transportation task in maritime transport. The approach based on predicted failure intensity in particular stages of ship operation is proposed.*

Keywords: *ship reliability, failure intensity*

Streszczenie: *W artykule przedstawiono niezawodność statku w czasie realizacji zadania transportowego w transporcie morskim. Zaproponowano podejście oparte na ocenie przewidywanej intensywności uszkodzeń w kolejnych etapach eksploatacji statku.*

Słowa kluczowe: *niezawodność statku, intensywność uszkodzeń*

1. Introduction

Prediction of safety of transportation tasks and reliability of ships in maritime transport is the most important problem in design and operation issues. Due to the complexity of the problems related to ship operation there is a need to determine the reliability of ship during transportation task at each operational stage.

2. Safety of maritime transportation and hazards in ship operation

Safety is the term of a broad interpretation and its formulation depends on the context and the assumed individual approach. The universal definitions of safety can be formulated as follows:

- freedom from danger, lack of hazards,
- freedom from unacceptable risks or personal injuries,
- not losing money, no financial losses.

Safety of transport is the characteristic of the realized transportation process characterized with lack of hazards to life and health of people and lack of hazards to the objects involved in this process as well as characterized with practical guaranties of lack of hazards in the possible to predict future [7].

Safety of maritime transportation is the characteristic of the realized operational process characterized with the lack of hazards to life and health of people, hazards to the object (ship) in the assumed state of environment, hydro-meteorological conditions [1, 2].

Safety of maritime navigation is the knowledge system, which main aim is determination of relationships and device of principles and operational methods to ensure safe navigation of seagoing and oceangoing ships during transport of people and goods along the maritime communication lines [3].

Maritime transportation is related to risk. The risk in dependence on navigational area – navigational conditions, hydro-meteorological conditions, vessel equipment, reliability of instruments and their technical condition and in dependence on crew qualifications and real abilities reach the different levels, cannot be eliminated and is only possible to be reduced [8].

Transport system can be defined as the system of technical, organisational and human means related with each other to realize transport of people and/or goods in time and space efficiently [5].

3. Reliability of transportation task in maritime transport

In the time of transportation task realisation the navigational process is realized. This process is related to the navigational reliability, which can be expressed as the probability that the vessel of the particular type in the assumed navigational and hydro-meteorological conditions, controlled by the navigator with proper qualifications in the certain time period and place will be inside the navigational path right for her movement direction, taking into account the safe under keel clearance and distance to the obstructions [4]. Reliability is interpreted in multidimensional way and means the remaining of the set level of safety and readiness along with the remaining of the set level of costs [6].

Fig. 1. Stages of operation of merchant ship: exposure, maritime event, critical event in uncertainty conditions, hazard, unexpected event, maritime failure, state of malfunction, maritime accident.

There are four basic states in ship operation: state I- port, state II – seagoing, state III – exclusion from operation, state IV – failure. State IV can appear in the three other states. These states are characterized with the different operational activities and procedures. The change of the operational state is characterized with consciousness, intentionality, ship master activity due to the realization of navigational process – realization of transportation task or activity with the aim of internal and external hazards elimination, resulting with maritime failure, state of unreliability and maritime accident.

The modern merchant vessels as the technical object are characterized with high complexity of the carried out operational tasks in different navigational environments. The results of a technical object failure are the hazards for the object, safety of people and sea environment. The state of failure (state of transitional worthiness) is the transitional state. The term “state of failure” is better characterising the current situation, points at the destructive processes in this state. It means, that there are particular changes in the object have become due to the primary unworthiness (failures), resulting with changes of the working part of the object characteristic, despite the fact the functional capabilities are maintained [2]. The areas of hazards in ship operation are presented in figure 2.

Fig. 2. The areas of hazards in ship operation: Merchant ship operation hazards: men, human error, terrorist hazards, technology of loading operations, freight and its characteristics, technical failures, technology, hydro-meteorological conditions, environment, navigational hazards.

The main hazards following from ship operation at sea and in port area are presented in figure 3.

Fig. 3. The fields of hazards in maritime transportation: port area – freight damage, loss of stability, oil spill in port area, damage of port infrastructure and ship during berthing and mooring operations, fire, technology of loading operations, other hazards; sea area – weather conditions, freight damage, ship construction damage, engine room failure, loss of stability, loss of ship, grounding, collision, ecological catastrophe, fire other hazards.

The manoeuvring hazards are as follows: loss of ship controllability, failure of propulsion, blackout, manoeuvring error, error during berthing and unberthing operations, error during anchoring, anchoring system failure.

The hazards caused by external conditions can appear when the weather conditions exceed the allowable design conditions for the ship and tugboats or the port operational parameters. Mainly it means the wind force exceeding the allowable values.

Merchant ship operation¹ is defined as the realization of transportation process (transport of passengers and goods) for the commercial purposes. The realization of the transportation task in maritime transportation and reliability of this task can be presented as the fault intensity diagram at particular stages of ship operation.

Fig. 4. Realization of transportation tasks under good weather conditions and during worsening of weather conditions - port manoeuvres, ship departure from the port, confined waters, open waters, port manoeuvre ship entry into the port, ship in port at the pier – loading operations.

¹ Kodeks morski, art. 2 § 1: Statkiem morskim jest każde urządzenie pływające przeznaczone lub używane do żeglugi morskiej, zwane dalej „statkiem”. Art. 3 § 1: Kodeks morski stosuje się do morskich statków handlowych. § 2: Morskim statkiem handlowym jest statek przeznaczony lub używany do prowadzenia działalności gospodarczej, a w szczególności do: przewozu ładunku lub pasażerów, rybołówstwa morskiego lub pozyskiwania innych zasobów morza, holowania, ratownictwa morskiego, wydobywania mienia zatopionego w morzu, pozyskiwania zasobów mineralnych dna morza oraz zasobów znajdującego się pod nim wnętrza Ziemi.

The fault intensity can be defined as follows:

$$\lambda(t) = \sum_{i=1}^6 \lambda_i(t) I_{A_i}(t)$$

where the indicator of the set : $A_i = [t_{i-1}, t_i)$, $i = 1, \dots, 6$ is expressed in the following form:

$$I_{A_i}(t) = \begin{cases} 1 & \text{dla } t \in A_i \\ 0 & \text{dla } t \notin A_i \end{cases}$$

The sets $A_i = [t_{i-1}, t_i)$, $i = 1, \dots, 6$ mean:

- $A_1 = [t_0, t_1)$ time interval of harbour manoeuvres
- $A_2 = [t_1, t_2)$ time interval of manoeuvres in confined waters
- $A_3 = [t_2, t_3)$ time interval of open sea navigation
- $A_4 = [t_3, t_4)$ time interval of manoeuvres in confined waters
- $A_5 = [t_4, t_5)$ time interval of harbour manoeuvres during ship entry into the harbour
- $A_6 = [t_5, t_6)$ time interval of harbour loading and unloading operations

The reliability function is described by the following equation:

$$R(t) = e^{-\int_0^t \lambda(u) du}, \quad t \geq 0$$

The value of reliability function for $t \in A_i = [t_{i-1}, t_i)$ is expressed by the equation:

$$R(t) = e^{-[\int_0^{t_1} \lambda_1(u) du + \dots + \int_{t_{i-1}}^t \lambda_i(u) du]}$$

4. Conclusion

The reliability of transportation task of merchant ship has been proposed to be expressed as fault intensity on the particular stages of ship operation. The fault intensity function and reliability function have been proposed.

5. References

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