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**IMPACT OF TANKERS' CONSTRUCTIVE
CHARACTERISTICS AND OPERATIONAL
CONDITIONS ON ACCIDENTAL OIL OUTFLOW
PROBABILITY AND SCALE**

**Summary of Doctoral Dissertation
Technological Sciences, Transport Engineering (03T)**

1432

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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Doctoral dissertation was prepared at Klaipėda University in 2002–2006.
The dissertation is defended as an external work.

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The dissertation will be defended at the public meeting of the Council of Scientific Field of Transport Engineering in the Senate Hall of Vilnius Gediminas Technical University at 9 a. m. on 20 December 2007.

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The summary of the doctoral dissertation was distributed on 19 November 2007.

A copy of the doctoral dissertation is available for review at the Library of Vilnius Gediminas Technical University (Saulėtekio al. 14, LT-10223 Vilnius, Lithuania).

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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Mindaugas ČESNAUSKIS

**TANKLAIVIŲ KONSTRUKCIJOS
YPATYBIŲ IR EKSPLOATACIJOS SĄLYGŲ
ĮTAKA AVARINIŲ NAFTOS IŠSILIEJIMŲ
TIKIMYBEI IR MASTAMS**

Daktaro disertacijos santrauka
Technologijos mokslai, transporto inžinerija (03T)

Vilnius  2007
LEIDYKLA
TECHNIKA

Disertacija rengta 2002–2006 metais Klaipėdos universitete.

Disertacija ginama eksternu.

Mokslinis konsultantas

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Disertacija ginama Vilniaus Gedimino technikos universiteto Transporto inžinerijos mokslo krypties taryboje:

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Disertacija bus ginama viešame Transporto inžinerijos mokslo krypties tarybos posėdyje 2007 m. gruodžio 20 d. 9 val. Vilniaus Gedimino technikos universiteto senato posėdžių salėje.

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Disertacijos santrauka išsiuntinėta 2007 m. lapkričio 19 d.

Disertaciją galima peržiūrėti Vilniaus Gedimino technikos universiteto bibliotekoje (Saulėtekio al. 14, LT-10223 Vilnius, Lietuva).

VGTU leidyklos „Technika“ 1432 mokslo literatūros knyga.

General characteristics of the dissertation

Topicality of the problem. Among the sources of pollution at sea, oil outflow from tankers during the accident, poses the biggest threat to the marine environment. Estimated probabilities of oil outflow event caused by tanker accident in different regions of the sea area, as well as calculated expected oil outflow, may provide a solid basis for optimal design of pollution combating means, it's expeditious deployment in case of tanker accident. However methods which are currently used for such evaluations are not sufficiently effective, in some cases they does not adequately account all crucial factors relevant for certain sea areas, in particular for those where intensity of tanker traffic is not high and statistical accident rate is low.

Therefore it is necessary to establish optimal and reliable method for estimation of probability of oil outflow event, as well as for prognosis of expected oil outflow in case of tanker accident. Next to this, the combination of results, obtained by applying these two methodologies, may be used for estimation of actual risk level, posed by tanker traffic in certain sea area.

Aim and tasks of the work. The dissertation provides with investigation of possibilities of prognosis of accidental oil outflow parameters. Theoretical assumptions for reduction of probability of oil outflow event from tanker as well as for minimization of consequences of tanker accident are proposed in the dissertation. In order to achieve the aim of dissertation, the following main tasks were formulated:

1. To assess all of the contributory factors, both objective and subjective, which have influence on accidental oil outflow and to propose assumptions for its' effective management.
2. By modeling the process of oil outflow event from tanker, to prepare the model of probabilistic assessment of oil outflow event, caused by tanker accident.
3. On the basis of results, obtained by conducting theoretical and experimental research, to prepare methodology for expeditious assessment of expected oil outflow from tanker in particular sea area.
4. On the basis of the results, obtained by researching tanker accidents in the Baltic sea as well as accidents with seagoing ships registered in Lithuania, to establish a list potential reasons, which may trigger tanker accident in Lithuanian responsibility sea area, and to propose theoretical assumptions for improvement of existing accident prevention level.

5. To assess actual oil spill risk level, caused by tankers operating in Lithuania's responsibility sea area, and to prepare recommendations for minimization of such risk.

Scientific novelty

Model of probabilistic assessment of oil outflow event caused by tanker accident is proposed in the dissertation. The model ensures, that all relevant available information (world and regional marine accident statistics, factors inherent to navigation area in question, etc.) is fully taken into account, and is recommended for prediction of oil outflow event probability distribution in different sectors of navigation area.

Methodology of research

The following methods of investigation have been applied: the comparative, statistical and complex analysis, and prognosis.

Practical value. The dissertation provides with modified version of probabilistic methodology, designed for estimation of expected cargo oil outflow from tanker involved in casualty. This methodology is recommended for expeditious estimation of oil outflow from tankers, which were involved in casualties (collisions or groundings) in the oil terminals, situated in the Baltic ports and its premises.

Defended propositions

1. Model of probabilistic assessment of oil outflow event caused by tanker accident.
2. Modified version of probabilistic methodology, designed for estimation of expected cargo oil outflow from tanker involved in casualty.
3. The results of research of technological factors, influencing tanker's hull actual condition.
4. The results of research of factors, which may have a considerable impact on tanker accident rate in Lithuania's responsibility sea area.

The scope of the scientific work. The scientific work consists of the general characteristic of the dissertation, four body chapters, conclusions, list of literature. The total scope of the dissertation – 125 pages, 45 figures and 35 tables. Literature references include 101 source.

1. Analysis of research works on accidental oil outflow from tankers and influencing factors

Analysis of research works on accidental oil outflow from tankers and influencing factors reveals a number of works that were carried out on tanker safety and pollution prevention matters both by Lithuania's and foreign scientists. The analysis lead to the following conclusions:

- the issues related to estimation methods of expected oil outflow and tanker accident probability have been thoroughly discussed by foreign researches. However, deployment of these methods in particular sea area can be improved, if additional data, related to that particular sea area will be used.
- majority of methods, used for estimation of oil outflow parameters as well as for estimation of accident probability are based on ships' accident statistics, additional factors are usually taken into account. However these methods, when applied for particular sea region, often disregard many relevant factors, or are too complex for practical use.

Hence the scientific issue shows up – on how to forecast oil outflow event probability and relevant oil outflow parameters for particular sea area, such as Lithuania's responsibility sea area.

2. Research of factors, which have influence on accidental oil outflow probability and scale

Accidents with tankers, like accidents with other ship types can be modeled as a separate process, containing different stages – initial prerequisites for the accident, reasons of the accident, initial incident which triggers the accident, tanker accident, oil outflow, and lastly – the consequences of the pollution to the environment. All the factors which have influence on accidental oil outflow probability and scale can be classified into the three major groups: 1) factors which have influence on the tanker accident probability, 2) factors which have influence on the oil outflow, immediately after the accident, and 3) factors influencing consequences to the marine environment. Oil outflow parameters in navigational area depends on the constructive and quantitative characteristics of the tankers operated in that area (constructive type, technical condition, crew qualification, ect.) as well as on the external factors relevant to that particular region. Therefore this part of the dissertation provides with an in depth analysis of these factors, with particular emphasis on the technological ones, closely related to the tanker hull design, construction and proper maintenance.

3. Methodologies for assessment of accidental oil outflow probability and scale

3.1. Model of probabilistic assessment of oil outflow event caused by tanker accident

In order to calculate probability of pollution, caused by tanker accident, two parameters are necessary – tanker accident rate in the navigation area and probability of pollution event, when tanker accident takes place. Prognosis of probability of tanker collision and stranding/grounding mainly is based on ships accident statistics. The probability of oil outflow event, triggered by collision or stranding/grounding, mostly depends on the construction of the hull of the tanker. In terms of reliability for the prognosis of such probability most suitable is probabilistic methodology, approved by the International Maritime Organization (IMO). There are no specific methodologies for evaluation of oil outflow event probability in case of fire or structural failure. Therefore the best way of evaluation of such events is to rely on the statistics. However methods described above are designed either for evaluation of pollution risk of particular tanker (in that case peculiarities of the region where tankers are operating remains disregarded), or on the contrary, concentrates on peculiarities of particular region (in that case tanker factors remains disregarded). Therefore these methods, when applied separately, can not ensure thorough and reliable prognosis of distribution of probability of oil outflow event in different sectors of the navigation area.

Approach, proposed in the dissertation ensures, that final result is obtained by complex evaluation of ship accident statistics, particulars of tankers operating in navigational area, as well as other dominating factors which may increase the reliability of the research.

The probability of oil outflow event from tanker in different sectors of navigational area due to different impact of environmental, navigational and other kind of factors, as well as due to existing traffic separation schemes in the area, may differ quite big number of times. In order to estimate distribution of such probability in different places of navigational area, the latter shall be divided in Z number of zones. In order to ensure high level of reliability of final result, the division of the area shall be performed in the manner that variation of the factors, dominating in each zone, and influencing tanker accident probability, would be as low as possible.

Estimations of oil outflow event probability distribution in each of the zones of navigational area is based on principle, that oil outflow event, triggered by tanker accident occurs as necessary event. Therefore the task is to

distribute the numeric value of this full probability to each of the modelled zones, by tanker accident category.

For any oil outflow event T , which may occur in zone z of the navigational area, we can model finite number M of scenarios S_{zm} . Let's assume, that any event T is triggered by one of the possible tanker accident categories – stranding/grounding (K_{z1}), collision (K_{z2}), fire/explosion (K_{z3}), or structural failure of the hull (K_{z4}). Then sum of probabilities of modelled tanker accident scenarios in particular zone z can be grouped by the accident categories:

$$P_z = \sum_{m=1}^M P(S_{zm}) = \sum_{k=1}^4 P(K_{zk}), \quad (1)$$

where P_z – probability of oil outflow event in zone z ; $P(S_{zm})$ – probability of appearance of m scenario in zone z ; $P(K_{zk})$ – probability of k category accident with tanker.

We can model $M, N, \dots, R$ numbers of scenarios for each of the zones of the navigational area. Sum of probabilities of scenarios, modelled for the whole navigational area will be equal to the sum of the probabilities of all oil outflow events, grouped by zone and by tanker accident category. Full probability of oil outflow event, triggered by tanker accident in whole navigational area will be equal:

$$\sum_{m=1}^M P(S_{1m}) + \sum_{n=1}^N P(S_{2n}) + \dots + \sum_{r=1}^R P(S_{Zr}) = \sum_{z=1}^Z \sum_{k=1}^4 P(K_{zk}). \quad (2)$$

Then, probability of k category tanker accident in zone z , followed by oil outflow – $P(K_{zk}|T)$, can be calculated according to English mathematician Bayesian theorem:

$$P(K_{zk} | T) = \frac{P(K_{zk}) \cdot P(T | K_{zk})}{\sum_{k=1}^4 P(K_{zk}) \cdot P(T | K_{zk})}, \quad (3)$$

where $P(T|K_{zk})$ – probability of oil outflow, in zone z which may occur due to k category tanker accident.

This model can be applied for calculation of oil outflow event caused by tanker accident probability distribution by zones and accident categories.

For preliminary estimation, absolute value of probability of at least single oil outflow event in navigational area per calendar year can be estimated according to Poisson's distribution:

$$P_{\Sigma T} = 1 - e^{-nP_{ty} \frac{t_{\Sigma} - t_k}{365}}, \quad (4)$$

where P_{ty} – average probability of accident of single operated tanker per year (loading and unloading time as well as repair time is not included); t_{Σ} – average operational time of tanker in navigational area (days); t_k – average tanker transshipment time in the terminal (days); k – probability, reflecting which part of tanker accidents triggers oil outflow, n – average number of tankers, entering the navigational area, per year.

3.2. Estimation of expected cargo oil outflow from tanker involved in casualty

Prognosis of amount of oil, passed to the sea during the tanker accident, mostly is needed in two cases:

1) when prediction of possible extent of oil pollution in particular port is exercised, having available input data on quantities of transported cargo oil, particulars of tankers used for such transportation and peculiarities of ports and it's oil terminals;

2) when preliminary expeditious estimation of occurred oil pollution is exercised, having only limited input technical data available (type of accident, port, type of tanker, quantity of cargo oil loaded, general particulars of tanker design).

The methodology approved by International Maritime Organization (IMO) for the estimation of oil outflow from tanker is used in dissertation as a basis. When applying this methodology, the volumes of each cargo tank and probabilities of possible damage of each of them is necessary to know, as an input data. Values of such probabilities can be calculated having main particulars of the hull and parameters, qualifying the exact position and shape of each cargo tank. However, this data in most cases is unavailable for expeditious use, as it usually is stored by shipbuilder or classification society, and can not be retrieved promptly. Aiming to ensure expeditious and, as precise as possible, estimations of cargo oil outflow having only limited primary information about the incident, the modified version of IMO approved simplified probabilistic methodology, designated for expeditious estimation of oil outflow from tanker, which was involved in accident in Lithuania's oil terminals (Klaipėda, Būtingė)

and it's operational zones and suffered hull damage, is suggested in the dissertation. In order to minimize amount of input data, necessary for oil outflow calculations, two assumptions are applied: the number of constructive designs of tankers is limited in certain sea region; it's hull and cargo tank geometrical characteristics are similar.

Data containing main particulars of the ship, total amount of volumes of cargo tanks V_{Σ} , cargo tank arrangement scheme, may be accessed via Internet in databases such as „Equasis“ or „LR Fairplay“. However parameters defining length of cargo tanks as well as cargo tank positions along the waterline ($x_{f(i)}$ and $x_{a(i)}$), see Fig 1, as well as other particulars defining the shape of cargo tanks are not stored in these databases.

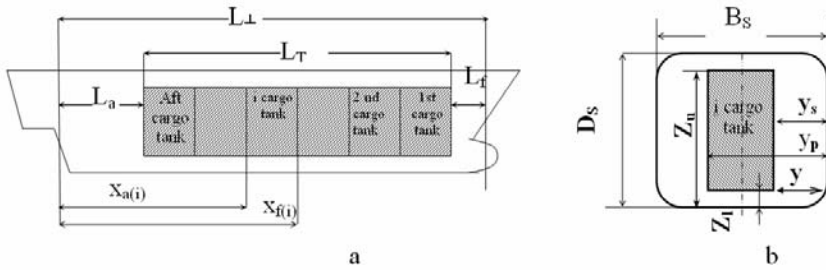


Fig 1. Dimensions of i cargo tank of the tanker: a – profile – looking inboard, b – section looking forward. Where: x_a – longitudinal distance from the aft to the aft most point on the cargo tank being considered; x_f – the longitudinal distance from the aft to the foremost point on the cargo tank being considered; B_s – moulded breadth; D_s – moulded depth; L_T – cumulative length of cargo tanks, arranged in one longitudinal line along the waterline; L_f – horizontal distance from front cargo compartment to front perpendicular; L_a – horizontal distance from aft cargo compartment to aft perpendicular; Z_l – the vertical distance from the moulded baseline to the lowest point on the cargo tank being considered; y – the minimum horizontal distance between the compartment under consideration and the starboard; y_s – the transverse distance from the starboard-most point on the cargo tank to vertical plate of the starboard; y_p – the transverse distance from the port – most point on the cargo tank to vertical plate of the starboard

Analysis of tankers having different sizes and design types revealed, that the length of all arranged cargo tanks for majority of tankers is the same, i.e. difference $x_{f(i)} - x_{a(i)}$ for the same tanker is constant value:

$$x_{f(i)} - x_{a(i)} = \frac{L_T}{n_{long}}, \quad (5)$$

$$L_T = L_{\perp} - (L_f + L_a), \quad (6)$$

where n_{long} – number of cargo tanks, arranged in one longitudinal line.

Initial volume of i cargo tank V_{ii} , m³, can be calculated as product of its length, width, height and corresponding volumetric coefficient:

$$V_{ii} = C_i (x_{f(i)} - x_{a(i)}) (y_{p(i)} - y_{s(i)}) (z_{u(i)} - z_{l(i)}), \quad (7)$$

where C_i – volumetric coefficient of i cargo tank.

In order to estimate volumetric coefficients for front and aft cargo tanks, the special research with 15 different design and deadweight tankers was conducted. The results of this research has shown, that notwithstanding to quite wide range of tanker design types, the tankers with similar tonnage and cargo tank arrangement scheme can be grouped and corresponding intervals of volumetric coefficients for front and aft cargo tanks can be imposed to those groups. After calculations of initial volumes V_{ii} , revised volumes V_i of each i cargo tank can be estimated:

$$V_i = \frac{V_{\Sigma}}{\sum_{i=1}^n V_{ii}} V_{ii}, \quad (8)$$

where V_{Σ} – total volume of all cargo tanks, known as one of the main particulars of the tanker; n – number of cargo tanks, arranged in the tanker.

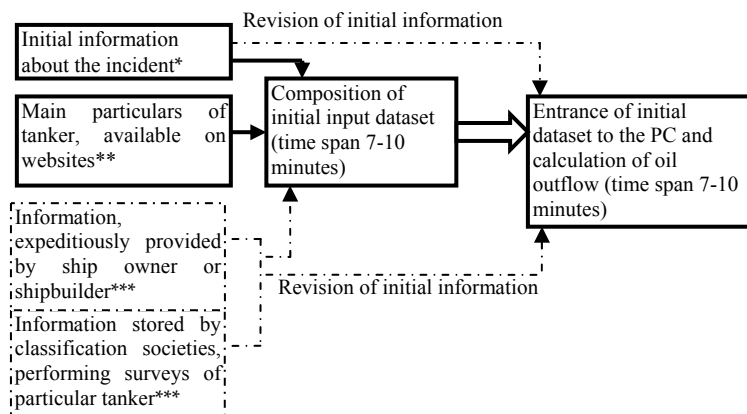
Calculations using this method were performed with 15 tankers. Errors of estimated volumes of each cargo tank comprised 2 – 7,5 %, comparing to the exact data, provided by tanker designers. Such errors may impose errors of calculated oil outflow up to 2,5 %. Assumptions and simplifications, proposed in the modified methodology, provides with the possibility, on the basis of very limited set of accident related data, to form the initial input dataset, necessary for application of the IMO approved probabilistic methodology. This dataset can be revised at any stage of estimation, when additional information on tanker design and/or accident circumstances becomes available. Table 1 provides with the references to the methods, to be used for calculations of complete set of parameters, necessary for application of IMO approved simplified probabilistic methodology.

Table 1. Parameters to be used for composition of initial dataset and relevant calculation methods (also refer to Fig 1)

Parameters, which in addition to main particulars are necessary for application of IMO approved simplified methodology		Method of calculation	Main particulars of the tanker
Cargo tank length, position along waterline	$x_{f(i)}, x_{a(i)}, L_m, L_p$	Refer to formulas (5) and (6) *	$DWT, n_{is}, L_{\perp}$
Cargo tank breadth, position across waterline	$y_{(i)}, y_{p(i)}$	*	K_s^{**}, y_s, B_s
Cargo tank height, position athwart waterline	Main particulars are sufficient	–	D_s, z_l
Cargo tank volume	V_i	Refer to formulas (7), (8) and (9)*	K_s^*, V_{Σ}
*Coefficients, necessary for calculations, are provided in the appropriate tables of the dissertation; ** Cargo tanks' dislocation scheme.			

In order to validate proposed modified methodology, comparative estimations were executed – estimation results obtained by using proposed modified methodology were compared with results obtained on the basis of strict application of IMO approved methodologies. Numeric values of mean oil outflow parameter (part of oil, spilled during the accident), estimated by modified methodology, were compared with values, obtained using IMO approved simplified probabilistic methodology and using exact tanker design parameters. Results of such evaluation shows, that numeric values of mean oil outflow parameter differ from 3 to 18 %. It is worth to note, that comparing output results estimated using probabilistic and simplified probabilistic methodologies (both approved by the IMO) and using the same input data provided by the tanker designer, mean oil outflow parameter differs up to 22 %.

Especially for application of proposed modified methodology, computer based calculation algorithm in MS „Excel“ was designed, which assures expeditious use of modified methodology. The application scheme of proposed modified methodology and peculiarities of application are presented in Fig 2. The modified methodology provides with the possibility, on the basis of very limited set of accident related data, to form initial input dataset, necessary for application of simplified probabilistic methodology. This dataset can be revised on any stage of estimation, when additional information on tanker design and/or accident circumstances becomes available. Such revision of data assures better accuracy of final result.



* Information about the type of casualty (collision or grounding), quantity of cargo oil loaded in the tanker, other additional information related to peculiarities of the incident.

** Main particulars of tanker design (length between perpendiculars, deadweight, moulded breadth, draught, moulded depth, number of cargo tanks and cargo tank arrangement scheme, distances between double hull and double bottom).

*** Additional data defining tanker design (distances, defining exact position and shape of each cargo tank, see Fig 1). This data is necessary for direct application of probabilistic and simplified probabilistic methodology and not necessary for use of modified methodology. However, when applying latter, this data may be entered to PC when the initial dataset, necessary for evaluation of oil outflow, is already composed.

Fig 2. Application scheme of modified methodology and peculiarities

4. Investigation and results of impact of tankers' constructive characteristics and operational conditions on accidental oil outflow probability and scale

For the application of methodologies, proposed in the dissertation, a number of parameters relevant for the LRSA, as well as for the Baltic Sea area were estimated. Investigation of relevant ships accident statistics is one of the crucial inputs for the assessment of parameters to be used for application of oil outflow probability evaluation model. It is worth to note, that factors which may influence tanker accident probability rate can be estimated not only by analysing accidents with tankers, but accidents with other types of ships as well.

Therefore research of accidents with seagoing ships, registered in Lithuanian authorities was conducted in this work. Main causes of such accidents – underestimation of meteorological conditions and water stream

impact during ship's mooring operations, inadequate selection of tugs for ship's transit in the port, improper watch of ship's position during mooring. Fig 3 provides with classification of accidents by the category.

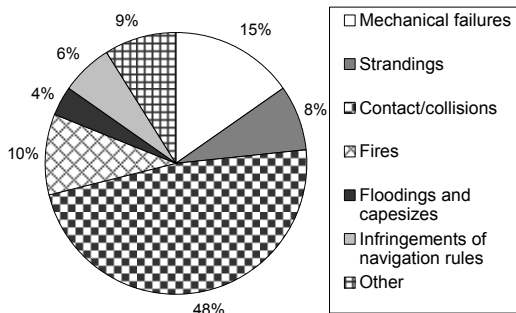


Fig 3. Classification of accidents with seagoing ships of by the category (data for the year 1999–2003, as registered by Lithuanian authorities)

A separate analysis of tanker accidents which took place in the Baltic Sea was conducted as well. The results of these investigations shows, that 90 percent of all accidents occurs due to the human error (including human error by designing and maintaining ship). The biggest number of errors takes place during the ship's exploitation period, i.e. due to errors of the crew. The technological factors, which, during exploitation of tanker, may potentially have negative impact on hull condition, and consequently on oil outflow probability and scale were investigated as well. The research shows, that biggest impact in this respect has proper application of anticorrosive coatings (in particular as regards for ballast and cargo tanks), proper maintenance of hull elements during exploitation period of the tanker, timely and proper repair of fatigue cracks in hull structures. It was estimated, that application of special anticorrosive systems, repair of the cracks, caused by cyclical loads, as regards to hull and it's elements, can give satisfactory results only when appropriate technologies are strictly complied.

Model of probabilistic assessment of oil outflow event caused by tanker accident was applied for Lithuania's responsibility sea area (LRSA). For this purpose LSRA was divided into six separate zones: 1 – zone includes Klaipėda port and it's approaches (in this zone transshipment of cargo is executed, tanker possibly may stand on the road), 2 – Būtingė oil terminal transshipment area, 3 – ships traffic lane to Klaipėda port, 4 – tanker traffic lane to and from Būtingė oil terminal, 5 – zone corresponds area, where exists probability of tanker stranding or grounding in case of deviation from course (area nearby the

coastline). The 6 zone contains remaining LRSA, with no tanker traffic. It is worth to note, that width of 3 and 4 zones is equal to 4 n.m., depths dominating in 5 zone may compromise safe navigation in terms of stranding/grounding. Therefore, division of LRSA was performed according to the principle of even distribution of factors, influencing accident probability in particular zone. Numeric values of oil outflow probability in case of tanker accident $P(T|K_{zk})$ were selected after consideration of juncture of tanker hull construction (in 2003–2006 overwhelming majority of tankers, which entered Būtingė oil terminal had double hull construction, and tankers, which entered Klaipėda port, were divided equally in terms of single and double hull construction). Parameters P_Z and $P(K_{zk})$ were set by shipping experts. Estimated oil outflow event full probability distribution by LRSA zones and by tanker accident category, calculated in accordance with (3) equation, shows, that highest rate of grounding/stranding probability is in the Klaipėda port area, which two times exceeds collision probability. However, more than two times credible, that oil outflow event in Klaipėda port area could occur due to collision, rather than due to grounding/stranding. For preliminary estimation of absolute value of probability of at least single oil outflow event in navigational area, it was assumed, that per calendar year $n = 600$ tankers enters LRSA, each of them operating there $t_{\Sigma} = 1,7$ days in average. Average tanker transshipment time in the terminal (Klaipėda port and Būtingė oil terminal) $t_k = 0,8$ days. According to the accident statistics, for tanker, operated in the world market, average accident probability rate per year (repair and transshipment times excluded) is equal to $P_y = 0,065$. According to pollution by tankers statistics, probability reflecting which part of tanker accidents triggers oil outflow is equal $k = 0,12$. Therefore, according to (4) equation $P_{\Sigma T} = 0,01147$ (approximately once per 87 years). For comparison, according to results presented in relevant study conducted by Klaipėda University in 1997, oil outflow event frequency in LRSA – 1 accident per 16–17 years. Such big differences resulted from different data used for estimations. The biggest impact was influenced by the fact that statistical frequency of tanker accidents declined sharply in the last decade. According to the data provided by Intertanko, in the time span between 1992 and 2004, tanker accident rate declined 5 times. Moreover, requirements related to maritime safety and pollution prevention from tankers, introduced by IMO in the last decade, in particular gradual elimination of single hull tankers from the world market, had positive impact to the reduction of oil outflow event probability rate.

Estimation of the quantity of expected oil outflow for LRSA was performed by using modified methodology. 19 different design tankers, comprising 33 % of the number of all tankers which enters Klaipėda Port or

Būtingė Oil Terminal per year, were estimated in terms of expected oil outflow in case of collision or grounding. For illustration of practical use of methodology, the estimation of possible oil outflow from tanker „Princess Pia“ was performed. The said tanker ran aground in the entrance channel of Klaipėda port in November of 2002, however no oil passed to the water at that time. Application of modified methodology provided with the result, that in case of oil outflow, the amount of oil spilled to the sea had amounted to 580 m³.

Performed estimations with tankers operated in LRSA revealed, that for double hull tankers mean oil outflow parameter does not exceed 0,015 – the maximum permissible numeric value of mean outflow parameter, required by MARPOL Convention. For double side and single hull tankers mean oil outflow parameter fluctuates from 0,026 to 0,094 (Fig 4).

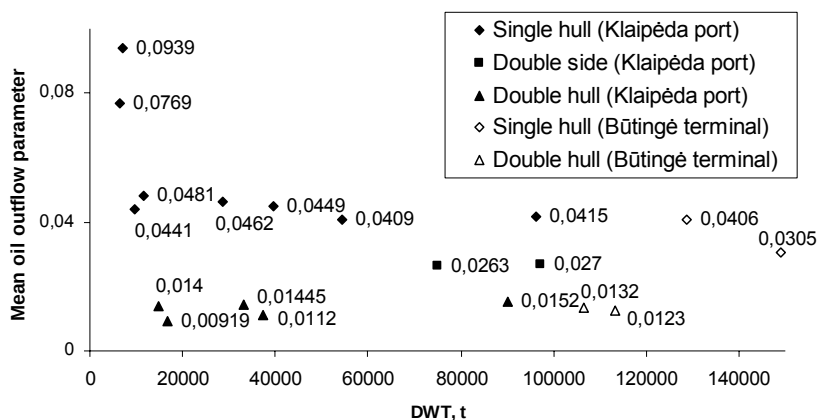


Fig 4. Estimated oil outflow parameters for some tankers, which entered Lithuanian ports

Following the classical risk definition, risk posed by tankers to the marine environment is defined as a product of probability of oil outflow event, caused by tanker accident and consequences to the marine environment, which is expressed by the quantity of oil spilled. This concept was used to estimate risk posed by tankers in LRSA. The results of the research shows, that risk level has a slight trend to decline over the past 10 years, and this trend will keep the similar pace at least until 2015–2020.

5. General conclusions

1. Investigation of statistics of marine accidents with tankers in the Baltic Sea, as well as with other seagoing ships, registered in Lithuania, was performed. Investigation revealed, that 58 out of 120 marine accidents registered in Lithuania during the year 1999–2003, took place in Klaipėda port, and 48 % of all registered accidents are classified as collisions or strandings or groundings.
2. For navigational areas with one or several oil terminals, where tanker traffic is not intensive, model of probabilistic assessment of oil outflow event, caused by tanker accident is proposed in the dissertation.
3. Estimations for Lithuania's responsibility sea area, using proposed model revealed that highest rate of grounding/stranding probability is in the Klaipėda port area, which two times exceeds collision probability. However, more than 2 times credible, that oil outflow event in Klaipėda port area will occur due to collision, rather than due to grounding/stranding. It was assessed that under current conditions tanker accident, followed by oil outflow, can occur once per 87 year.
4. Application of International Maritime Organization approved methodologies for estimations of oil outflow from tankers provides with reliable results, but only when quite big amount of input data is available. The modification of International Maritime Organization approved simplified probabilistic methodology, suitable for expeditious use in particular sea region, is proposed, in which, the amount of input data is reduced several times, knowing in advance the types of tankers, operating in this region, and its main design characteristics.
5. Comparative calculations revealed, that estimations of mean oil outflow, performed using modified methodology differs from those performed with exact methodologies not more than 18 %, and this difference does not exceeds differences of results, calculated by exact application of two different International Maritime Organization approved methodologies. The modified methodology is recommended for expeditious estimation of oil outflow from tankers, which were involved in casualties (collisions or groundings) in the oil terminals, situated in the Baltic ports and its premises.
6. Risk, posed by tankers to the marine environment was assessed for Lithuania's responsibility sea area, using classical risk definition. Practical application of such approach is based on actual level of accidental oil outflow probability and quantity of oil spilled during tanker accident. This approach is also suggested for decision making for Lithuanian authorities,

when tankers of higher risk enter Lithuania's responsibility sea area and enhancement of preparedness level is considered.

**List of published works on the topic of the dissertation
In the reviewed scientific periodical publications**

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2. ČESNAUSKIS, M. Model of Probabilistic Assessment of Oil Outflow Event Caused by Tanker Accident. *Transport*, 2007, Vol. XXII, No. 3, p. 187 – 194. ISSN 1648-4142 (ISI Master List)
3. ČESNAUSKIS, M.; TARASEVIČIUS, R. Analysis of Statistics and Investigations of Marine Casualties, Registered in Lithuanian Competent Authorities During the Period of 1999–2003. *Jūra ir aplinka*, 2004, Vol. 2, p. 33 – 40 (in Lithuanian).

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4. ČESNAUSKIS, M. Analysis of marine accidents, registered by Lithuanian Maritime Administration during 1999–2003. *Technologijos mokslo darbai vakarų Lietuvoje*, 2004, Vol. IV, p. 168 – 174 (in Lithuanian).

About the author

Mindaugas Česnauskis was born in Klaipėda, on 16 of November, 1973. First degree in Marine Transport Engineering, Faculty of Marine Transport Technologies, Klaipėda University, 1995. Diploma engineer (engineer on board) professional qualification, Faculty of Marine Transport Technologies, Klaipėda University, 1996. In 1997–1998 was on the position as mechanical engineer at Klaipėda State Seaport Authority. 2000–2002 – at Klaipėda State Seaport Authority as Head of IMO information centre. Master of Science in Transport and Maritime Management, Institute of Transport and Maritime Management, Antwerp University, 2000. 2002–2006 – PhD student at Klaipėda University. Currently working in Lithuanian Maritime Safety Administration, as Head of International Relations Department and assistant in Maritime Institute, Klaipėda University.

TANKLAIVIŲ KONSTRUKCIJOS YPATYBIŲ IR EKSPLOATACIJOS SĄLYGŲ ĮTAKA AVARINIŲ NAFTOS IŠSILIEJIMŲ TIKIMYBEI IR MASTAMS

Mokslo problemos aktualumas

Didžiausia tiesioginė žala jūrinei aplinkai bei netiesioginė žala pakrantės valstybių ekonomikai padaroma tanklaivių avarijų metu, kada į aplinką išsilieja dideli kiekiai gabenamo krovinio. Reagavimo į taršą jūroje sistemų projektavimas, operatyvus jų panaudojimas likviduojant tanklaivių avarijų padarinius, siejamas su patikimomis bei operatyviomis tanklaivių avarijų ir jų sukeltos taršos parametru prognozėmis. Egzistuoja problema, kad šiuo metu naudojami prognozavimo metodai yra nepakankamai efektyvūs, jais dažnai nevysiškai įvertinami avarinių naftos išsiliejamų incidentų tikimybę bei mastus įtakojantys veiksniai, ypač kada šie metodai taikomi konkretiems laivybos rajonams, kuriuose tanklaivių eismas nėra intensyvus ir tanklaivių avarijos yra itin retos.

Todėl būtina ištirti, kaip įvertinti labiausiai tikėtinas avarinių naftos išsiliejamų incidentų vietas konkrečiame laivybos rajone, bei kaip operatyviai prognozuoti tanklaivio avarijos metu į aplinką patekusio naftos ar kitokio tanklaivio transportuojamo krovinio kiekį. Be to šių parametru įvertinimas sudaro galimybę įvertinti tanklaivių keliamą riziką jūros aplinkai.

Darbo tikslas ir uždaviniai

Ištirti avarinį naftos išsiliejamą iš tanklaivio apibūdinančių parametru prognozavimo galimybes. Suformuluoti teorines prielaidas avarinio naftos išsiliejamų incidento tikimybę sumažinti, bei tanklaivio avarijų padarinių mastams sušvelninti. Darbo tikslui pasiekti buvo suformuluoti šie uždaviniai:

1. Įvertinti avarinius naftos išsiliejamus iš tanklaivių įtakojančių objektyvių ir subjektyvių veiksnių visumą, bei nustatyti prielaidas šiems veiksniams valdyti.
2. Modeliuojant avarinės taršos iš tanklaivių procesą, parengti avarinio naftos išsiliejamų iš tanklaivio tikimybinio įvertinimo modelį.
3. Remiantis atliktų eksperimentinių bei teorinių tyrimų rezultatais parengti metodiką, leidžiančią operatyviai prognozuoti galimus avarinių naftos išsiliejamų mastus konkrečiame laivybos rajone.
4. Atliekant Baltijos jūroje įvykusių tanklaivių avarijų bei Lietuvoje įregistruotų laivų avarijų statistikos eksperimentinį tyrimą, nustatyti potencialias priežastis, galinčias sukelti tanklaivio avariją Lietuvos

atsakomybės rajone, bei suformuluoti teorines prielaidas tokių avarių prevencijai.

5. Įvertinti Lietuvos atsakomybės rajone operuojančių tanklaivių keliamą naftos išsiliejimų incidentų riziką, bei parengti šios rizikos mažinimo rekomendacijas.

Mokslinis naujumas

Pasiūlytas avarinio naftos išsiliejimo iš tanklaivio tikimybinio įvertinimo modelis, kurį, panaudojant kiek įmanoma daugiau tyrimui aktualios informacijos (pasaulinė ir regioninė laivų avarių statistika, tiriamame laivybos rajone dominuojantys veiksniai), rekomenduojama taikyti prognozuojant tanklaivio avarijos sukeltos taršos tikimybės pasiskirstymą atskirose tiriamo laivybos rajono zonose.

Tyrimų metodika

Disertacijos rengimo metu buvo naudoti šie metodai: statistinės analizės ir prognozavimo, kompleksinės analizės.

Praktinė vertė

Darbe patikslinta naftos išsiliejimo iš avariją patyrusio tanklaivio tikimybinė skaičiavimo metodika ją pritaikant apibendrintiems galimų avarinių naftos išsiliejimų iš tam tikrų konstrukcijos parametrų tanklaivių skaičiavimams, bei operatyviam preliminariam įvykusio naftos išsiliejimo masto įvertinimui pagal pačius primityviausius techninius duomenis apie avariją (avarijos tipas, uostas, tanklaivio tipas, jame esantis pakrautas naftos ar jos produktų kiekis, pagrindiniai tanklaivio konstrukcijos parametrai).

Ginamieji teiginiai

1. Avarinio naftos išsiliejimo iš tanklaivio tikimybinio įvertinimo metodika.
2. Patikslinta avarinių naftos išsiliejimų mastų tikimybinė skaičiavimo metodika.
3. Technologinių veiksnių, įtakančių eksploatuojamo tanklaivio korpuso konstrukcijų techninę būklę, tyrimo rezultatai.
4. Veiksnių, galinčių nulemti tanklaivių avaringumą Lietuvos atsakomybės rajone, tyrimų rezultatai.

Darbo apimtis. Darbą sudaro įvadas, 4 skyriai, išvados ir literatūros sąrašas. Bendra disertacijos apimtis – 125 puslapiai, 45 iliustracijos ir 35 lentelės. Pirmame disertacijos skyriuje atlikta avarinių naftos išsiliejimo incidentų iš tanklaivių mokslinių darbų analizė. Skyriaus pabaigoje

suformuluota mokslinė problema – kaip nustatyti būdingus avarinė taršą iš tanklaivių įtakojančius veiksniai ir prognozuoti avarinius naftos išsiliejimus konkrečiame rajone. Antrame skyriuje nagrinėjami veiksniai, įtakojantys naftos išsiliejimų tikimybę ir mastus. Išnagrinėti tanklaivių konstrukcijų pažeidimų atvejai (susidūrimas/atsitrenkimas ir užplaukimas ant seklumos/grunto lietimas), tanklaivio korpuso struktūros pažeidimai bei technologiniai veiksniai, lemiantys korpuso konstrukcijų techninę būklę. Trečiame skyriuje pateikti avarinių naftos išsiliejimų tikimybės ir mastų įvertinimo metodai. Ketvirtame skyriuje pritaikomos avarinių naftos išsiliejimų metodikos vertinant ir prognozuojant naftos išsiliejimus Baltijos jūros Lietuvos atsakomybės rajone. Gauti vertinimo rezultatai palyginti su kitomis metodikomis gautais rezultatais.

Bendrosios išvados

1. Atlikus Baltijos jūroje įvykusių tanklaivių avarių bei Lietuvoje įregistruotų laivų avarių statistikos eksperimentinį tyrimą, apibendrintos priežastys, dėl kurių gali kilti tanklaivių avarijos Lietuvos atsakomybės rajone, bei suformuluotos teorinės prielaidos tokių avarių prevencijai. Atliktas tyrimas parodė, kad 58 iš 120 Lietuvoje 1999–2003 metų laikotarpiu įregistruotų jūrų laivų avarių įvyko Klaipėdos uoste, o 48 % visų įregistruotų avarių klasifikuojamos kaip susidūrimai ar atsitrenkimai.
2. Disertacijoje pasiūlytas avarinio naftos išsiliejimo iš tanklaivio tikimybinio įvertinimo modelis, skirtas tanklaivio avarijos sukulto naftos išsiliejimo tikimybės pasiskirstymui laivybos rajone prognozuoti. Modelis rekomenduojamas laivybos rajonams su vienu ar keliais naftos terminalais, kuriuose vyrauja nedidelio intensyvumo tanklaivių eismas.
3. Taikant disertacijoje pasiūlytą avarinio naftos išsiliejimo iš tanklaivio tikimybinio įvertinimo modelį Lietuvos atsakomybės jūros rajonui nustatyta, kad tanklaivio užplaukimo ant seklumos tikimybė yra didžiausia Klaipėdos uosto zonoje ir du kartus viršija susidūrimo ar atsitrenkimo tikimybę. Tačiau daugiau ne 2 kartus labiau tikėtina, kad avarinis naftos išsiliejimas Klaipėdos uosto zonoje įvyks dėl tanklaivio susidūrimo ar atsitrenkimo, nei dėl užplaukimo ant seklumos ar grunto lietimo. Įvertinta, kad tanklaivio avarija su naftos išsiliejimu Lietuvos atsakomybės rajone vidutiniškai gali įvykti kartą per 87 metus.
4. Prognozuojant jau įvykusio tanklaivio incidento metu tikėtiną išsiliejusios naftos kiekį naudojamos Tarptautinės jūrų organizacijos aprobuotos universalios metodikos duoda patikimus rezultatus tik turint palyginti didelį masyvą duomenų, daugelis iš kurių operatyviai nepasiekiami. Operatyviam naudojimui, konkrečiame jūros regione disertacijoje pasiūlytas modifikuotas Tarptautinės jūrų organizacijos patvirtintos metodikos variantas, kuriame

pradinių duomenų kiekis yra kelis kartus sumažintas remiantis būdingais šiam rajonui tanklaivių tipais ir jų pagrindinėmis konstrukcijos charakteristikomis.

5. Atlikti lyginamieji skaičiavimai parodė, kad vertinant tikėtiną naftos išsiliejimo dydį, modifikuota metodika gaunami rezultatai skiriasi nuo gautų panaudojant pripažintas metodikas ne daugiau kaip 18 % ir šis skirtumas yra ne didesnis negu naudojant skirtingas Tarptautinės jūrų organizacijos patvirtintas detalias metodikas. Modifikuota metodika rekomenduojama operatyvaus, tikėtinai išsiliejusios naftos kiekio įvertinimui Baltijos jūroje esančių naftos terminalų operatyvinėse zonose ir jų jūrinėse prieigose.
6. Disertacijoje atliktas tanklaivių keliamos rizikos jūros aplinkai įvertinimas, kuris remiasi avarinio naftos išsiliejimo tikimybės ir tikėtino avarijos metu išsiliejusio naftos kiekio faktinių dydžių nustatymu. Tokį vertinimą, pagal disertacijoje pasiūlytą procedūrą, rekomenduojama taikyti ir institucijoms, priimančioms sprendimą dėl sustiprinto reagavimo į galimą taršą parengties lygio, blogesnės techninės būklės tanklaiviams planuojant įplaukti į Lietuvos atsakomybės rajoną.

Trumpos žinios apie autorių

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**IMPACT OF TANKERS' CONSTRUCTIVE CHARACTERISTICS AND
OPERATIONAL CONDITIONS ON ACCIDENTAL OIL OUTFLOW
PROBABILITY AND SCALE**

Summary of Doctoral Dissertation

Technological Sciences, Transport Engineering (03T)

Mindaugas Česnauskis

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AVARINIŲ NAFTOS IŠSILIEJIMŲ TIKIMYBEI IR MASTAMS**

Daktaro disertacijos santrauka

Technologijos mokslai, transporto inžinerija (03T)

2007 11 12. 1,5 sp. l. Tiražas 100 egz.

Vilniaus Gedimino technikos universiteto

leidykla „Technika“, Saulėtekio al. 11, LT-10223 Vilnius, <http://leidykla.vgtu.lt>

Spausdino UAB „Baltijos kopija“,

Kareivių g. 13B, 09109 Vilnius, www.kopija.lt