METHODOLOGICAL APPROACH TO TRAINING MARITIME SPECIALISTS FOR THE RISK ASSESSMENT OF EMERGENCIES IN NAVIGATION

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Abstract The paper considers the methodological bases of the maritime specialists' readiness formation to the risk assessment and predicting an emergency development. To create the special competencies an approach to definition of the educational content for creating the special competencies is proposed. It allows future maritime specialists to make appropriate decisions both to assess possible emergency situations and to make actions to prevent its occurrence. Also a practical-oriented methodology of assessment of the risks of emergencies and their development is considered on a real example of the navigation practice. It is assumed that the operating analysis of the current technical state of the ship, long-term statistics of its navigation practice allows to determine the character and causes of the possible failures of ship's equipment. In order to assess the situation and to make a correct decision an algorithm of actions of the ship officers is suggested to fulfill the use of the scenarios method and the method of the fault tree analysis (FTA). The paper illustrates the concrete scenario with two versions of the most unfavorable dynamics of emergency development and describes approaches to the calculation of probability assessments of the events.

Keywords: risks prediction, emergency situation, scenario method, fault tree analysis, sample of emergency.

1. Methodological bases for the formation of readiness of maritime specialists to assessment and management of the risk of emergencies

The reliable assessment of risks in navigation and their effective management come to the choice of methods and means to provide specified (normative) values of safety indicators with the minimum amount of necessary resources for realization. The system of the risk management is a set of interrelated processes and operations aimed at achieving a single goal: reducing the level of the risk. The risk management system is characterized with the most important processes and operations: monitoring the ships operating conditions, identification and analysis of risks that occur or may be possible; developing, planning, organization and the control measures implementation to eliminate or reduce the level of risks; an analysis of the effectiveness of planned and implemented measures and their long-term consequences; positive achievements and negative experiences; a risk factor analysis based on retrospective data and expert assessments. The system based on the requirements of the International Safety Management Code (ISM Code) and Formal Safety Assessment (FSA) is used now into the safety management practice. But shipping companies solve the issues of assessing and managing the risks of emergencies mainly at the empirical level (the control of compliance with the requirements of normative documents in terms of safety of navigation is made). This is due to the following reasons: 1) The methodological basis for assessing and managing the risks of emergencies in navigation is insufficiently developed at present; 2) Maritime specialists do not receive proper educational training in the context of the development of relevant competencies in the field of the risk assessment and management. Thus, on the one hand, reducing the rate of casualties requires the search for new effective methods for managing the safety of navigation. On the other hand, the level of the competence of maritime specialists in assessing and managing risks is insufficient. Also the further development of the methodology of the assessment and risk management is required. It is possible to eliminate this contradiction by solving two main tasks: educational and scientific (Moiseenko, 2004).

The present paper is devoted to the methodological approach to determining the contents of training and the formation of functionally necessary competencies for future maritime specialists in the field of the maritime safety management and the risks of emergencies at sea. The definition of a set of competences and the elaboration of programs for their formation requires, first of all, the study of maritime transportation processes and risk management operations. It is possible to determine the external and internal factors affecting the process, to identify casualties' risk factors as a result of the study. Development of the analytical readiness of the maritime specialist is a necessary condition for the analysis of processes and risk factors. It is formed through the development of such competencies as: the ability to use knowledge in the field of mathematical disciplines, the systems theory and analysis, the philosophy and the logics. The knowledge of these subjects is necessary for the analysis of processes and systems (for example, transport), information, the accident rate. It is also very important to get abilities for monitoring external and internal environment; to generalization and formalization of processes. The study of technological processes of maritime transportation allows to determine the main competencies that are necessary for solving the tasks of risk management. For example, the maritime specialist has to have the abilities to assess the level of the risk of the maritime cargo transportation on the basis of knowledge of the transport and physical properties of the cargo; to perform calculations of fastening deck cargo and assess its reliability and the "behavior" of the ship under extreme conditions of navigation (Moiseenko, 2004; Moiseenko and Meyler, 2011). The knowledge of the theory of risks and the research of operations, theoretical bases of managing and decision-making, organization of maritime transportation and transport logistics form the special competence of a maritime specialist. He will be able to identify qualitative and calculate quantitative risk assessments and its price; to develop measures to reduce risks, to elaborate administrative decisions, etc. Thus, in the process of training, the future specialists study almost the whole set of disciplines, whose knowledge is used to solve the problems of assessing and managing the risk of emergencies. However, as our analysis shows, they are not fully ready functionally to solve the tasks of risk assessment and management. The main reason is that specialists do not have a methodological approach to risk assessment and management, since there are no an integrative discipline or sections in the training programs where the issues of risk assessment and management would be systematically stated. In this regard, the task of monitoring the level of competence of maritime specialists in the field of risk management and safety of navigation, as well as determining the content and methods of developing professionalism in this area of activity is relevant. It is associated with certain difficulties, which are due, first of all, to the specifics of the activity of seafarers.

Firstly, for the effective implementation of this work the specialist should be qualified to solve various practical problems in the field, for example, navigation or fish catching, technical exploitation of the ship as well as the production - economical, commercial and legal activities. Secondly, it often has no a possibility to get qualified third-party assistance when a ship works at sea; there are difficulties with diagnosing problems. Thirdly, due to the specificity of their work, maritime specialists should use self-development and self-improvement as priority forms of professional development (Moiseenko, 2004). The content of maritime specialists training is represented as a combination of the following components: a system of subject' theoretical knowledge and the main trends in the development of the scientific and technological progress; professional activity and social experience; abilities and skills of researching the object of activity, i.e. skill in handling to the method of the system analysis; abilities to integrate knowledge in different subjects and use them to solve practical problems.

2. Assessment of the risks of emergencies and the dynamics of their development

Let's consider a practice-oriented methodology for assessing the risks of emergencies and the dynamics of their development on a concrete example from the navigational practice (Moiseenko, 2009). The m/v "JOHN N" has a course 20 degrees to port of Durban along the Eastern coast of South Africa. An analysis of the technical condition of the ship and the statistics of work of the main engine and steering shows that there is a possibility of a failure. In particular, the forced shutdown of the main engine was happened about 20 times, the steering system breakdown occurred 5 times within last 3 years. It is necessary to note that the ship was far from the best technical condition and its age was more than 20 years. In order to ensure the safety of navigation, we show on this example the method of forecasting of the risk occurrence and the development of an emergency situation. Initial in-formation for the analysis: the distance to the coast is 15 miles; the nature of the coast is rocky; the depths under the keel are more than 150 m.; the wind NNE 7 m/s; the current of the south direction at a speed of 1 to 1.5 knots. In this situation, there are risks of failure of the main engine or steering. What should be the algorithm for immediate action of commanding officers of the ship in the case of an emergency?

The first action of the captain of the ship: to report to the ship-owner and the insurance company about the existing problem (an incident) and the current situation. Then, if it is possible, to contact to the near situated ships with a request to be in touch (within a few hours of a trip) till a full assessment of the situation and decision making. Actions of the chief engineer of the emergency ship: to find out the reasons for the engine shutdown or the steering system breakdown and the nature of these failures. The main threat is that ship can run aground or go on the rocky shore under unfavorable circumstances if the route of the ship is near the coast. At the open sea it should pay main attention to the stability and other seagoing abilities of the ship. The algorithm of further actions of the ship officers is suggested to fulfill using the method of scenarios (Lindgren and Bandhold, 2003) and the method of the Fault Tree Analysis (Sutton, 2011) in order to assess the situation and to make a correct decision. The comprehensive method of scenarios is proposed for predicting complex processes with structural changes. It consists in establishing a logically connected sequence of step-by-step transition events from the existing state of the prediction object to the future state. Time is usually an essential factor when predicting by the method of scenarios, i.e. the process develops in time. The scenario of the development of the emergency situation is shown in Fig. 1. The scenario presents the two most unfavorable variants of the dynamics of the emergency development. The analysis of the scenarios allows to state that the most unfavorable variant includes the events: 1 - 2 - 3 - 6 - 8 - 9 - 11 - 14 - 15. However, the second variant: 1 - 2 - 3 - 7 - 8 - 10 - 12 is also dangerous, but such a danger can arise only if the wind increases to the level of "storm". Let's further to assume that the weather forecast at this area is favorable for the next three days. Let us consider the threats to the ship on the variant № 1 of the emergency situation development. The anchor does not hold in this variant because of the depth is more than 120 m, and the ground is rocky. As a result the ship will drift with the speed of around 1.7 miles per hour under the wind speed of 7 m/s and the current speed of 1.5 knots. In this case the ship will drift 6.5 hours to a depth of 120-150 m. At this depth the ship will be situated at the distance of 3.5 miles from the shallow. The anchor will be on the rocky ground and the ship will continue to drift with the speed of about 0.4 miles per hour. The ship will be on the shallow within 8.7 hours. Thus, the ship will be on the coastal stony ground after 15 hours from the moment of the engine failure. Let us suppose that the cause of the main engine failure is associated with a fracture in the ground of the plunger of the cylinder and damage to the exhaust manifold (due to an explosion of oil cooling the ground of the plunger). In this case it is necessary to replace the plunger and put the bandage on the fracture in the manifold. According to experts, these works will take 15-17 hours. Therefore, it is necessary to "keep" the ship at a safe distance from the coastal shallow for at least 18 hours. In this regard, the rescue ship should be at the area of the emergency ship in full readiness in the next 5-6 hours. The decision to involve a rescue ship for towing the emergency ship should be taken on the basis of an analysis of the dynamics of the emergency situation development. A tree of failures reflecting the dynamics of the emergencies development is shown in Fig. 2. The tree is developed in order to identify the cause-effect relationships and calculate predictive assessments of the emergency development. Grounding the ship and its damage is the top of a tree (the point M). Two events which can lead to the ship grounding are branches of the tree. These events are connected to the top of the tree by the condition "and" because of grounding can occur under the condition of simultaneous occurrence of both these events. There are difficulties to determine quantitative values of probabilistic estimates of the events occurrence. Two cases can be here: 1) The distribution law of random variables/events is known and there is a representative statistics which is typical for frequently recurring events; 2) The law of distribution of random variables/events is unknown, which is typical for conditions of an uncertainty, i.e. the occurrence is weak studied.

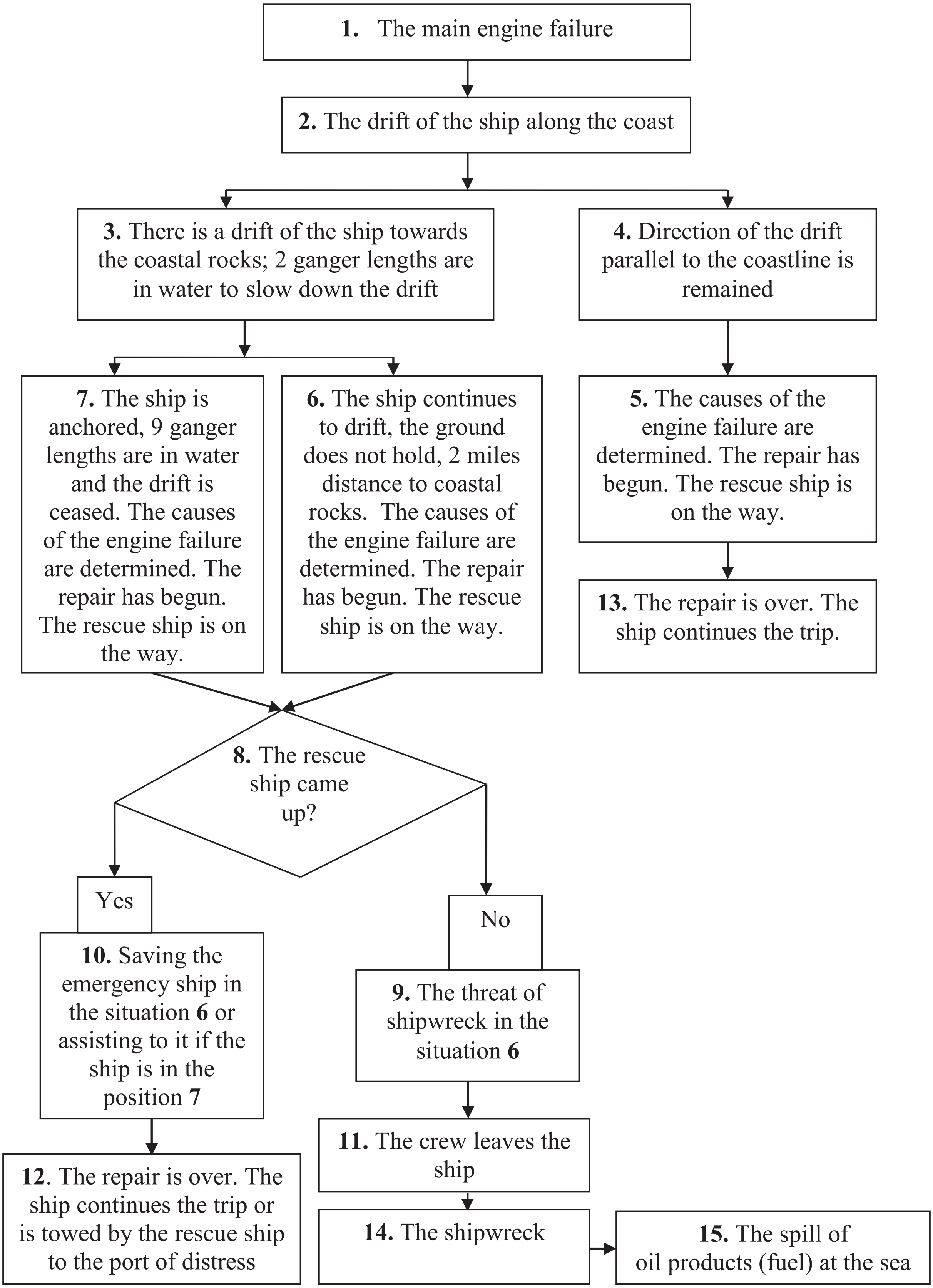

Figure 1. The scenario of the development of the emergency situation

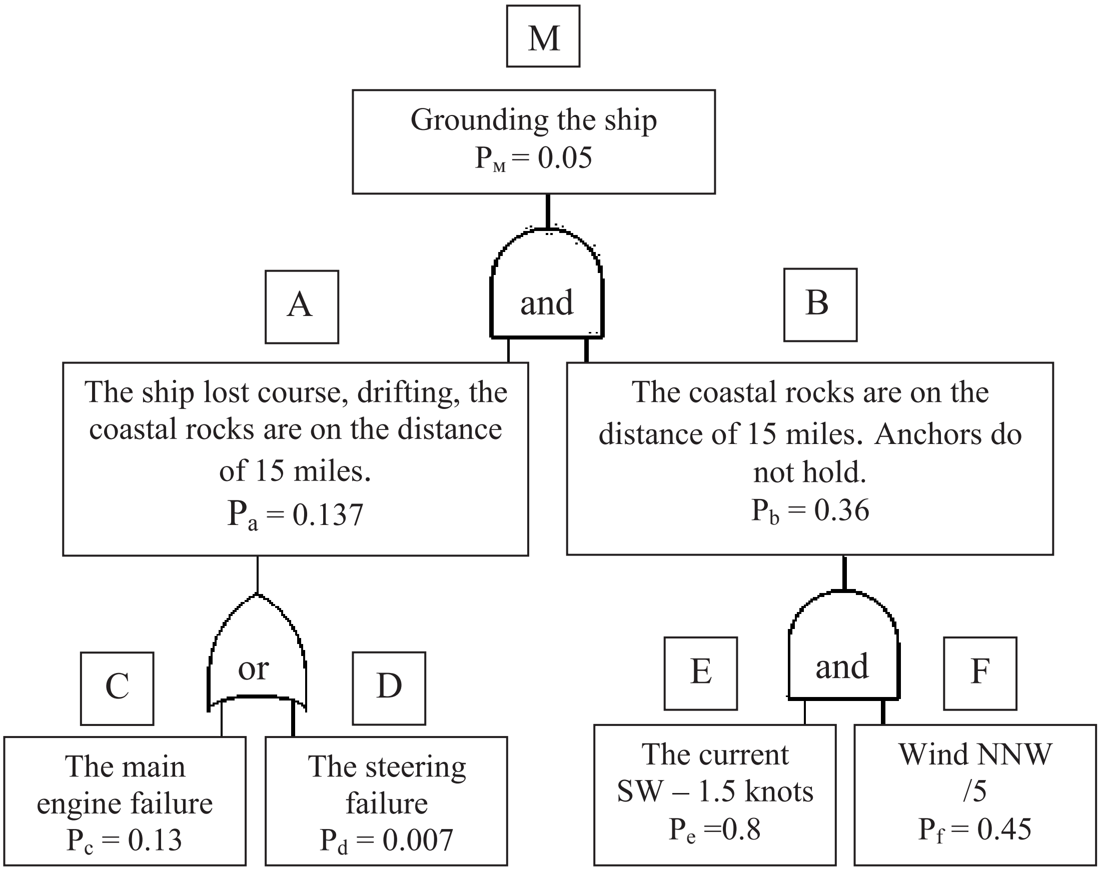

Figure 2. Tree of failures (faults)

Thus, obtaining quantitative estimates of probability is not difficult in the first case. In the second case, if the law of distribution of random variables/events is unknown, it is assumed that the random variables have a β-distribution. The choice of this law cannot be strictly justified. It has a density function that resembles the Gaussian law but is limited to the left and the right. The β - distribution considered in the context of the described problem is chosen to calculate the probability of a random event occurrence and the dispersion by known formulae (Ventzel and Ovcharov, 2016). The minimum, most probable and maximum values of the probability are determined by experts. The experts' opinion was based on the analysis of data on the failures of the main engine and steering system of the "JHON-N" ships type (Moiseenko and Meyler, 2011). Probabilistic estimates for the current and wind were determined on the basis of the analysis of the wind rose for the considered season/month of the year, the current' map and the sailing directions data. Synoptic maps and weather forecasts of coastal hydrometeorological stations were analyzed in the short-term perspective. The probabilistic estimates for each of these events are shown in Fig. 2. The signs "and", "or" are used when events changed. Probabilistic estimates of events are multiplied in the case of the "and" sign. The estimates are added in the case of the "or" sign. For example, M = AB; A = C + D; B = EF. Probabilistic estimates of the events occurrence can be determined by the method of fuzzy numbers, but this method is more time consuming and requires a large number of calculations and also gives an approximate result. The Failure Tree Analysis (FTA) shows that the risk of the ship grounding i.e. the frequency of the occurrence of an event is within ($10^{-1} \div 10^{-2}$). There is a case of the critical event. The risk will be lower than the allowable one if safety measures are taken. It may be advisable to set the course of the ship at the definite distance from the dangers. In this case the ship can drift on clean water 18-20 hours, i.e. time required for repairing the main engine failure. The main task of the captain is to take all possible measures to keep the ship on deep water before the arrival of the rescue ship. It is necessary to develop and implement a plan of measures aimed for reducing the risk of grounding. Thus, the scenario and the tree of failures reflect the dynamics of the emergency situation development. Two main outcomes are possible in case of grounding of the ship: 1) Constructive destruction of the ship in case of severe weather conditions (winds of the western directions with the speed over than 20 m/s); 2) Damages of the hull are limited by holes in the bottom of the ship and the weather allows rescue operations. So, the ship-owner and the insurance company will take the decision to remove the ship off the rocks. The damage will be calculated either based on the fact of the ship destruction, or on the fact of the ship removal off the rocks and its towing to the port of distress. The tree of failures described above is a variant of the forecast of an emergency situation development and all calculations should be considered as a priori. How to assess the situation in the case of real events, when an emergency engine shutdown has already occurred? In this case the calculation of the risk of the ship grounding should be based on the al-ready occurred event, i.e. the failure of the main engine. So, the probability of the failure is assumed equal to $P_c = 1$ and hence $P_a = 1$ also. Then the probability of occurrence of the ship grounding, i.e. the event M: $P_m = AB = 1 \cdot 0.29 = 0.29$. This is already a high level of a danger which belongs to the critical group according to the scale: $10^{-1} \div 10^{-2}$ (Baldin and Vorobiev, 2012). It requires additional security measures. The most effective measure is towing the emergency ship by a rescue ship. Further, depending on the situation with the repair of the main engine, a decision is made: either continue the trip or to tow the ship to the port of distress.

Conclusion

Training maritime specialists for the risk assessment is an important element of their education. Therefore, it is necessary to improve the methodological basis for assessing and managing risks in navigation in order to develop appropriate competencies and, as a consequence, to reduce the accident rate on the fleet. It is necessary to include in the curriculum disciplines that provide knowledge of the system theory, the system analysis, the risk theory and operations research, the theoretical foundations of management and decision-making, the organization of transportation and the transport logistics. The above is supported by a concrete example of the possible development of an emergency situation at sea. A real methodology for forecasting and making decisions is demonstrated. The maritime specialist should be able to "design" an emergency scenario, to give probabilistic assessments of events and to analyze the development of the situation.

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