ESTIMATION OF UNDESIRABLE EVENTS IN OPERATION OF BULK CARRIERS

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Abstract

This paper describes the introduced results of researches of undesirable events at one shipowner for a period of twelve years. The study included mostly merchant vessels bulk carriers and their significant objects. The ships were decomposed on functional systems and elements also divided them into of the navigation and machinery part. There was carried out a quantitative and economics analysis. In the economic analysis have been exchange rates accounted.

Attempted classification of the causes of the event and its participation in material losses incurred. These events are also a threat to human life and health as well as the natural environment. One showed on methods and means of diagnostics as manner of limitation their sizes and results. The results should be useful in the design of diagnostic experiments to select the objects that should be subject monitored.

The larges losses of adverse events were initiated in the functional systems: navigation, main drive and cargo. The most often adverse events are collisions. The most expensive vessel objects in the engine room proved to be reciprocating internal combustion engines for main propulsion and auxiliary. The investigations were conducted for all types of reciprocating internal combustion engines mounted on the test vessels. Combustion engines were operated under different external and internal conditions and were feed distillate and residual fuel oils.

Keywords: *bulk carriers, functional systems, elements,* adverse events, *piston marine diesel engines*

1. Introduction

Safety is a property of a technical object consisting of capability to function in certain conditions and in period of time without the occurrence of accidents [10]. The main lines of action in order to improve safety include: prevention of adverse events and reduce risks (loss prevention). In the operation of technical object has been distinguished safety of: process, operator and environment.

On the proper operation of the ship and the safety of navigation, is affected by many factors, which can be divided into the following [1, 2, 4, 6]:

- correct navigation – maintaining the recommended shipping routes, adjust the speed and course of the ship to weather conditions and hazards route (narrow passageways, traffic density, etc.), ensuring the stability and buoyancy of the vessel,
- reliability of equipment and systems – main propulsion, auxiliary and emergency procedures,
- cargo security – maintaining standardized conditions of lading.

Despite the use of sophisticated diagnostic systems, there are adverse events of ships and their equipment, and the final operation decision take the operator – (navigator or engineer) and he is responsible for the consequences of their selections.

Experts say that the number of accidents at sea showed downward trends and ships in the world sailing can be considered to be more secure.

2. Decomposition method

A motor ship is a complex system, so the choice to research of object is important. The system is a set of elements called objects, related to each other and the relationship between elements R:

$$O = \{O_1, O_2, ..., O_n, R_1, R_2, ..., R_m\}, \quad (1)$$

where:
O_1 – element of the system O, i = 1, 2, ..., n,
R_j –relationships between elements of the system, j = 1, 2, ..., m.

Maritime ship to transport of bulk cargo is divided into a deck and machinery equipment, and functional systems. In literature, a division of vessels on the functional systems was different [1–3, 6, 10, 11], and so for the purposes of this work it was decided to make the decomposition takes into account the literature and the book of Safety Management Systems of shipowner. Separated systems have been allocated to deck crew and black gang (Fig. 1). In some cases, navigation and engine room elements belong to the single system. Often the user of the system is member of the deck crew and behind the technical state is responsible representative of the machinery crew.

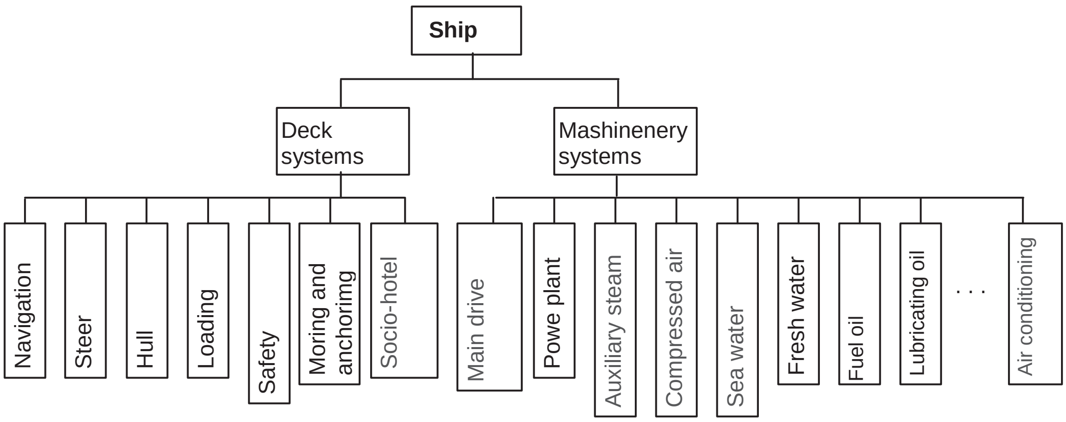

Fig. 1. Graphical representation of the multi-level system

In the navigation part are distinguished: navigation system (path planning and trajectory control, anti-collision, communication, signal, recording the journey), steering systems (transmission and transfer equipment of directions, steering gear, rudder with rudder stock), hull system (including watertight bulkheads), cargo (cargo facilities, closing hatches, holds, mountings, cooling's, ventilations, drainages), safety system (hull leakproofness monitoring, fire monitoring, protective hull stress monitoring, emergency, medical service, emergency communications), mooring and anchoring (device equipment, anchoring and towing equipment), socio-hotel (nutrition, residential, utilization of hotel garbage).

In the engine room have been distinguished of systems [5, 6, 11]: main drive, power plant, auxiliary steam, compressed air, sea water, fresh water, fuel oil, lubricating oil, exhaust gases, bilge, ballast, cooling and air conditioning.

The significance of the subsystem can be determined by a set of criteria. As a criterion to determine the significance of the subsystem can be adopted integral over time or space, and the parameters defining the characteristics of the system state based on the size of the check Φ_i is contained in a fixed range of variation:

$$a \le \Phi_i \le b. \quad (2)$$

Thus, the importance of the subsystem and is a function of the degree of fulfilment of the conditions set by K_i criteria:

$$I = f(K_1, K_2, ..., K_i, ..., K_n), \quad i = 1, 2, ..., n. \quad (3)$$

At the conclusion of the period set by the criterion can be assigned a value of 1, and if the opposite instance 0, the relationship takes the form:

$$I = f(0,1,...)\,. \tag{4}$$

In the bulk carrier you can also selected the important elements, among others, on the basis of the frequency and costs of adverse events [2, 4].

The investigations included a period of 12 years where investigated 1040 adverse events. It is sufficient sample to inference about state of population [2]. The investigations were conducted in the operation conditions of ships mainly by observation.

3. Results and analysis

For analysis of adverse events of the bulk carriers can be applied selected indicators of reliability and cost (the size of the losses and damage) that may arise as a result of adverse events [2, 4, 7]: the number of failures, turn-off time from operation, repair time and the cost of repair. Reliability is one of the characteristics of marine vessels and one of the factors ensuring the proper functioning of the ship, to ensure the safety of people, of cargo, of floating object and realization of tasks [2]. In the operation of vessels can be divided into states: stop in port, input and output maneuvers, sea voyage. Disruption of the production process vessel: the change of motion parameters or detention, prolonged stay in port, stay in the yard or temporary withdrawal from service.

The unreliability of the deck or machine object was caused the failure of the ship. Operating time of object to the failure state can be written as:

$$t_{BS} = \min\{t_{B1}, t_{B2}, t_{B3}, ..., t_{Bn}\}\,, \tag{5}$$

where t_{BS} is a correct time of work of *i*-th object to instant of failure.

For the selected populations of ships a measure of those losses for the period (t, $t + \Delta t$) can be described by the relationship [7]:

$$S(t, t+\Delta t) = \sum_{i=1}^{n(t,t+\Delta t)} S_i\,, \tag{6}$$

where S_i is a collective loss caused by the occurrence of the *i*-th of the event in the period (t, $t + \Delta$t), and $n = 1, 2, ..., \infty$ is the number of adverse events in this period.

$$S_i = \sum_{j=1}^{k} S_{ij}\,, \tag{7}$$

where S_{ij} is a waste of an individual loss referenced to the *j*-th ship, due to the *i*-th undesirable event.

Collective losses can be presented in relative formulate and expressed as a percentage:

$$S_{zi} = \frac{S_i}{S(t, t+\Delta t)} \cdot 100\%\,. \tag{8}$$

The measure of the criticality of failure is determined by the relationship:

$$U_k = F_{ri}\, C_{Fi}\, W_{bi}\, W_{wui}\,, \tag{9}$$

where:

F_{ri} – frequency of the *i*-th damage,

C_{Fi} – consumer price index of fault state,

W_{bi} – safety factor,

W_{wui} – indicator of secondary failures caused of the i-th damage.

The losses due to the occurrence of adverse events were higher the navigation parts than engine room (Fig. 2). These losses of adverse events in the deck parts were three times larger than the engine room objects. Some adverse events occurred in the unfavourable external and internal conditions.

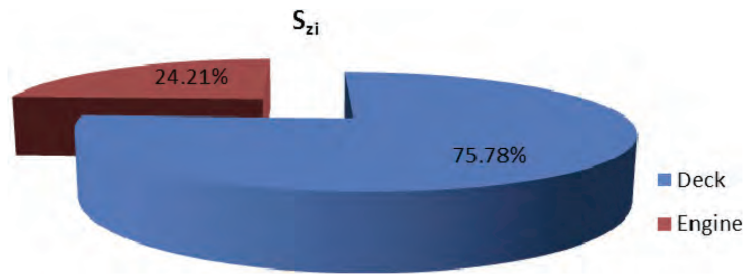

Fig. 2. Share of collective losses S_{zi} of adverse events deck parts and engine room

Environmental conditions for the ship shall specify: air humidity, air temperature, air pressure, pollution, exposure to biotic conditions swimming, shipping region, the sea state, wind direction, etc.

In the distinguished of functional systems the largest losses were incurred due to adverse events initiated in the systems: navigation, propulsion and cargo (Fig. 3). In the navigation system dominated the losses caused by collisions of vessels with other floating objects and with the quay or sluice, entering on shoal etc. Fig. 4 shows the handling of the vessel after the collision with a passenger ferry.

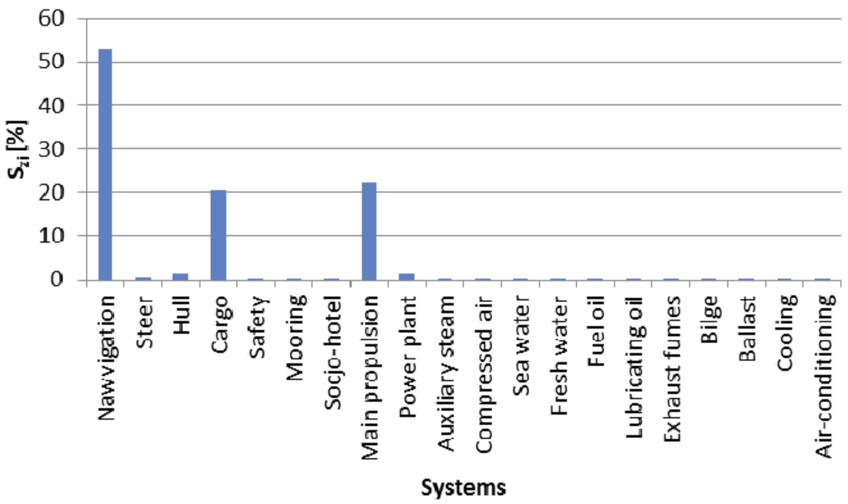

Fig. 3. Share of collective losses of adverse events specific functional systems of investigated vessels

Fig. 4. Repair the ship after damage to the hull in a collision

In a cargo system dominated of failures of vessels caused during loading and unloading.

Adverse events caused the main propulsion were primarily failures of reciprocating internal combustion engines and the instantaneous unavailability for action. Fig. 5 shows the cracked cylinder liner of marine main engine 6RLB66 type. The RL series engine is a single-acting, reversible two-stroke marine diesel engine with exhaust-gas turbocharging and backflow scavenging for direct propeller drive. The continuous part of the scavenge-air receiver serves as scavenging duct.

Fig. 5. View of cracked cylinder liner

The main engines were also often failures of pistons and cylinder heads. Fig. 6 shows broken piston rings of main drive engine.

In the engine room were significant losses due to failures to the auxiliary engines. There was dominated by the losses caused by fires and damaging the piston-crank system. Fig. 7 shows the abrasive wear of crank pin and unacceptable circularity error.

Fig. 6. Brocken piston rings of main engine

Fig. 7. Unacceptably worn of crank pin of the auxiliary engines delivered residual fuel and operated under tropical conditions

An anthropo-technical system of ship is in upstate, if its subsystems are in upstate:

$$SZ_{SAT} \Leftrightarrow (SZ_T \cap SZ_C \cap SZ_Ś), \tag{10}$$

where:
SZ_T – up state of the technique,
SZ_C – up state of the of the man,
$SZ_Ś$ – up state of the of the environment for shipping.

Figure 8 show that the operators were the biggest perpetrators of losses of adverse events (75%), and environment least. Also the man often has accidents, and then dealt with in a separate paper [8]. In second place was a technical failure of the vessel. A damaging interaction of environment on the ship and crew are: storms, thunderstorms, ice conditions, etc. The damage caused by the environment was minimal (Fig. 8).

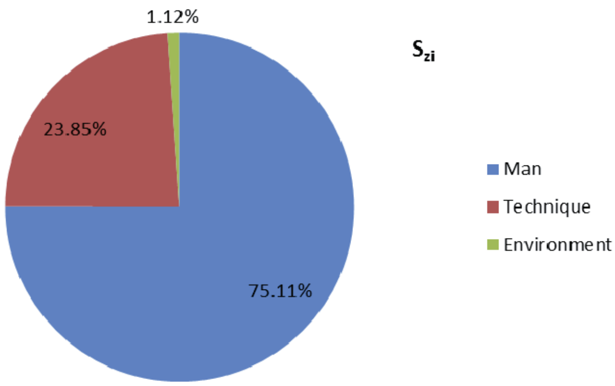

Fig. 8. Collective losses of adverse events caused by: man, technique and the environment

On many ships were run diagnostic tests, especially in recent years, but the results of investigations which suggested a state of unavailability of technical facilities not always convinced of the crew.

4. Resume

The vessel requires a significant investment in the design, manufacturing, operation and disposal. Some undesirable events leading to large losses, so it should be minimized.

The floating objects should be studied as athropo-technical systems: man–technique–environment.

Greater attention is needed to man than the products of technique, because they were the cause of adverse events in more than 75% of cases. In order to improve the reliability of the operator's one ought to larger selection of them by means of medical diagnostics at the time of the medical examination and selection of crew. The second form of increasing the efficiency of the crew is to improve the quality of training and quality control methods of knowledge.

Therefore, in addition to the progress of the staff using it and supporting it right is considered the progress of automation in order to take numerous steps of monitoring and control. It is also advisable the improve state of anti-collision systems.

In complex systems anthropo-technical such as marine vessels to reduce the number and sizes of adverse events it is appropriate to adopt on a large scale and modernization of methods and means of technical diagnostics. Diagnosis should be used primarily for objects with large losses of their occurrence.

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