ANALYSIS OF COMPARTMENTS FLOODING TIME AND METACENTRIC HEIGHT AFTER HULL DAMAGE

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Summary

The paper presents research on damage stability and unsinkability. The result of it is a valuable source of knowledge of behaving a ship while flooding its compartments. In the paper, a short description of accidents and damages of Polish warships taking place in 1985-2004 is presented. The time when compartments are flooded (t_f) and stability parameters are one of the key elements which have influence on a rescue action. The knowledge of the time mentioned and a metacentric height (GM) are very important for a commanding officer making decisions while damage of the ship. To provide the information about the time t_f a new method was designed. Firstly, volume of damaged compartments was calculated. To estimate a real quantity of the water, the permeability of flooding compartment μ is used. Permeability of the main engine and auxiliary power plant was estimated on the basis of preliminary research presented in the paper. Its value, shown in the article, is dependent on the water level inside compartments. The metacentric height (GM), while flooding process of damage compartments, was calculated in the next step. On the basic of the built computer program, a simulation of the flooding process and value of metacentric height (GM) of the damaged main engine and auxiliary power plant ship's type 888 was shown. The developed method was tested experimentally and results of the tests are presented in the paper. The results of the experiments can be a base to define general rules to make proper decisions during the process of damage control.

Keywords: damage stability, survivability, flooding time of compartment.

ANALIZA CZASU ZATOPIENIA PRZEDZIAŁU OKRĘTOWEGO I WYSOKOŚCI METACENTRYCZNEJ PO USZKODZENIU KADŁUBA

Streszczenie

W artykule zaprezentowano wyniki badań stateczności awaryjnej i niezatapialności okrętu stanowiące źródło wiedzy o zachowaniu się okrętu podczas zatapiania jego przedziałów. Przedstawiono krótką charakterystykę wypadków i awarii okrętowych w latach 1985 – 2004. Podstawowymi elementami sygnalizowanymi w artykule są czas zatopienia przedziału okrętowego i parametry stateczności mające wpływ na bezpieczeństwo okrętu i prowadzenie akcji ratowniczej. Znajomość wymienionych parametrów jest bardzo istotna dla oficera odpowiedzialnego za akcję ratowniczą i niezbędna do wypracowania decyzji o sposobie jej prowadzenia. Do określenia czasu zatopienia przedziału okrętowego opracowano nową metodę. W pierwszej kolejności określono objętość uszkodzonego przedziału. W celu oceny rzeczywistej ilości wody napływającej do uszkodzonego przedziału wykorzystano współczynnik zatapialności przedziału, którego wartość dla siłowni głównej i pomocniczej określono dla rosnącego poziomu wody w przedziale. Następnie na podstawie zbudowanego programu komputerowego obliczono i przedstawiono graficznie wyniki wartości wysokości metacentrycznej oraz symulację zatapiania przedziałów siłowni głównej i pomocniczej. Otrzymane wyniki badań eksperymentalnych mogą być podstawą do opracowania metod walki z awariami w ramach obrony przeciwawaryjnej okrętu.

Słowa kluczowe: stateczność awaryjna, niezatapialność, czas zatopienia przedziału.

INTRODUCTION

Even highly organized fleets struggle with accidents and technical breakdowns which cannot be completely eliminated. The breakdowns can be classified based on their causes. The basic causes of the breakdowns are: warfare, defects of materials and defects within the production process, constructional defects, technological defects in the process of renovation, material's wear and tear, not meeting the requirements in operating and servicing an equipment, not taking security measures while storing dangerous cargoes, e.g. explosive materials, petroleum products and other chemical components of serious fire hazard, environmental hazards.

A partial or total loss in functionality of mechanisms and installations can occur both during warfare and during daily operating a ship.

Failures caused by navigational errors or wrong maneuvering represent a group of ship accidents and breakdowns which can lead to dangerous loss of buoyancy of a ship due to flooding its compartments.

The statistical data prepared by the Polish Navy Commission of Warship Accidents and breakdowns reveal 156 warship accidents and breakdowns between 1985 and 2004. The data mentioned are presented in figure 1 [3].

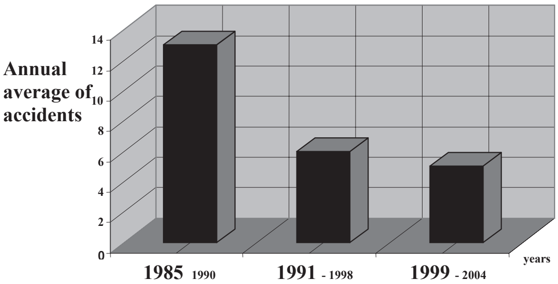


Fig. 1. The overall graph of accidents and breakdowns between 1985- 2004

In a situation of a breakdown crew activities deciding about ability of a warship to fight should be directed to take a proper actions during the process of damage control and to protect stability and maneuverability of the ship.

Exercises within the boundaries of the process of damage control, apart from construction solutions, increase the safety of both the ship and the crew. Training is carried out in well prepared training centers which are situated in the United Kingdom, Germany, Netherlands and Pakistan. The centers are equipped with ship models designed for simulating failure states which most frequently occur while operating a ship. The same models were also used in the experiments reported in the paper. One of the goals of the experiments mentioned was to determine the following parameters: t_f and GM for the ship type 888. This warship is used for training of Polish seafarers taking part in numerous international cruises. Main dimensions of the ship are: length L-72 m, breadth B-12 m, draught T-4,2 m and displacement 1750 t. Photo of the ship is shown in Figure 2.

Presently, only simplified methods to calculate the parameters above mentioned exist. The method presented in the paper has a distinctive difference compared to the existing, similar methods discussed in some publications. The worked out method considers the permeability value dependent on the water level inside the damaged compartment. Due to this, we can estimate more accurately the quantity of water in the compartment and finally more accurately the flooding time of the damaged compartment. The aim of presented method is to provide experimental validation.

Fig.2. Ship type 888

The information about t_f and stability parameters is very important for a commanding officer. It enables him to make a proper decision during the process of damage control. The officer, based on the information should determine the point in time, when further fighting for survivability is senseless and when all effort should be directed to save the crew and documents.

COMPUTING THE VOLUME OF DAMAGED COMPARTMENTS

The volume and shape of damaged compartments is necessary to present a simulation process of flooding compartments. The lines plan of the ship's hull is used to compute the theoretical volume. Moreover, the plan was also used to have sections extracted at the place of ribs number 35, 40, 45, 50, where we can find the damaged compartment. The sections are shown in Figure 3 [4, 6].

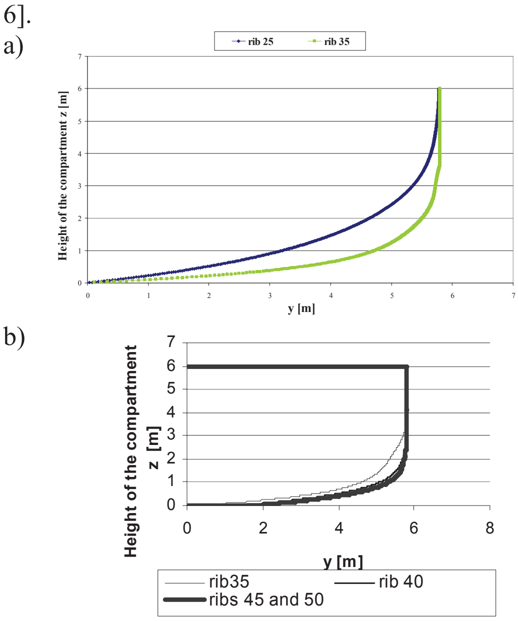
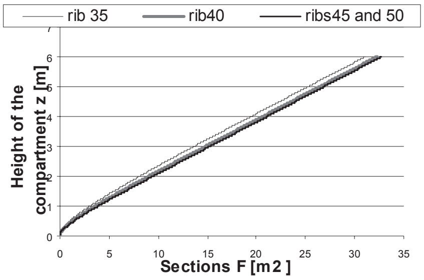


Fig. 3. Sections of: a) auxiliary power plant, b) engine room

The area of the sections was calculated to estimate the accurate volume of the damaged compartment. Integral curves of sectional areas, obtained in this way, are presented in graphic form as a multinomial degree 7 in Figure 4.

a)



b)

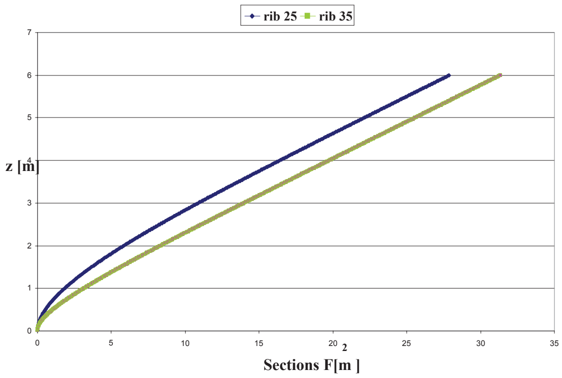


Fig. 4. Integral curve sectional areas: a) engine room, b) auxiliary power plant

Using section areas and a distance between them, the theoretical compartment volume can be calculated, by the formula [1,2]:

$$v_t = \sum \frac{(F_i + F_{i+1}) \cdot l_w}{2} \tag{1}$$

where l_w = the distance between sectional areas

F_i, F_{i+1} = section areas.

THE PERMEABILITY CALCULATION

The volume of the empty compartment was calculated with the aid of the computer program. The real quantity of the water, flooding the compartment, is less than the theoretical volume of the compartment due to the volume of all mechanisms and devices inside the compartment. Usually, to calculate a real quantity of the water, the permeability of flooding compartment μ is used. Permeability is used in ship survivability and damaged stability calculations. In this case, the permeability of a space is a coefficient from 0 to 1. The permeability of a space is the percentage of volume of the space which may be occupied by seawater if the space is flooded. The remaining volume (not filled with seawater) being occupied by machinery, cargo, accommodation spaces, etc.

The values of permeability for compartment is calculated by the formula [1]:

$$\mu = \frac{V}{V_t} \tag{2}$$

where v_t = theoretical compartment volume;

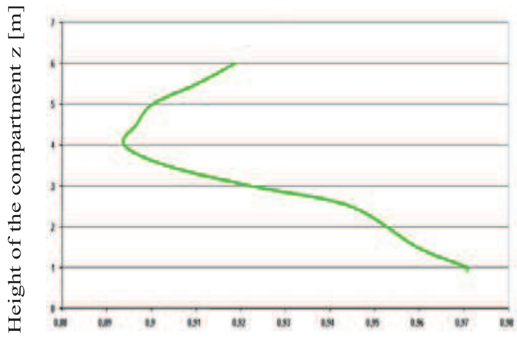
v = real quantity of the water inside the compartment.

The numerical value of the permeability depends on both, a kind and destination of damaged compartment. The permeability of the compartment μ, which is announced in the SOLAS Convention, is usually used to calculate the real volume of the compartment. Typical values from the SOLAS Convention are:

- 0.95 for voids (empty spaces), tanks, and living spaces;
- 0.85 for machinery spaces;
- 0.60 for spaces allocated to stores.

This implies that for damaged stability calculation purposes, machinery spaces are only 15% full with machinery by volume (100% - 85% = 15%). In preliminary research presented in the paper, permeability of the main engine room and the auxiliary power plant was estimated. Its value depends on the height of the water inside the compartment. The graph of the permeability is shown in Figure 5 [4, 6].

a)



The permeability μ_v

b)

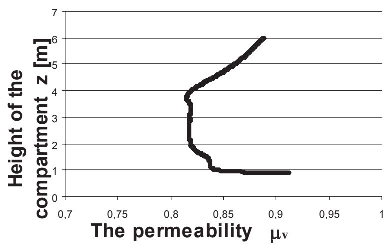


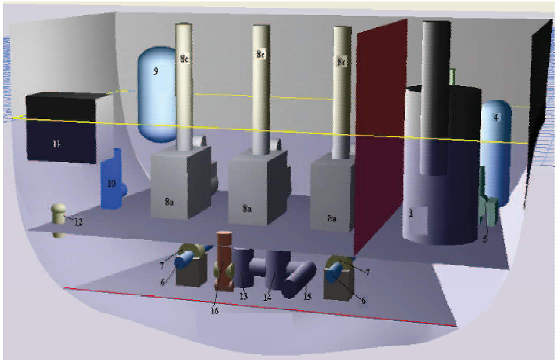
Fig. 5. Graph of permeability: a) the auxiliary power plant, b) the engine room permeability μv

The average value of the permeability for chosen compartments, obtained as a result of experiments, is comparable with the value of the SOLAS Convention and equals 0,84.

THE MODEL OF SIMULATION FOR DAMAGED COMPARTMENTS

The simulation models of the auxiliary power plant and the engine room, equipped with all main mechanisms and devices, were made in the next part of the research. The view of the compartments being flooded and the position of the ship are shown in Figure 6 [4, 6].

a)



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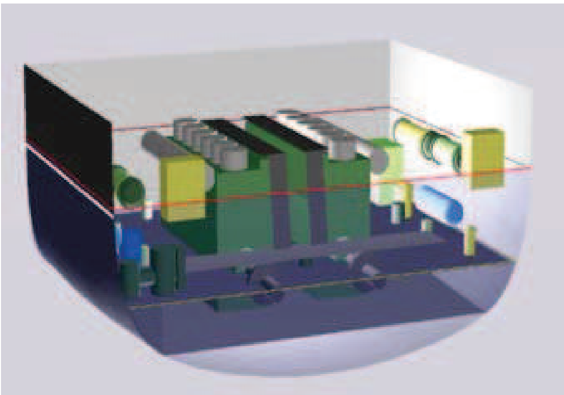

Fig. 6. Compartments being flooded: a) auxiliary power plant, b) engine room

THE ANALYSIS OF THE INFLUENCE OF DAMAGE PARAMETERS ON THETIME T_F FOR THE COMPARTMENT SHIP TYPE 888

The experimental research on t_f for engine room ship type 888 was carried out for different parameters of damages. In the research, the place and the dimensions of damage were taken into consideration.

During the numerical simulation t_f of damaged compartment, the variability volumetric flow rate of the water flowing to the compartment was taken into account. This parameter depends on both the depth of the hole and water level inside the compartment. Assuming, that the flooding process is a hydrostatic, the movement of the vessel was not taken into consideration and the ship is without a heel and trim. Only the draft of the ship caused by the adoption of water to the damaged compartment was taken into account.

In the first stage of the research, t_f for the engine room was estimated. The calculations of t_f were made for the following example conditions: ship's draught T=4 m, the dimension of damages R=0,03 m, R=0,05 m, R=0,1 m and R=0,2 m (R- denotes radius). The holes were placed from 0,1m to 3,0 m below the surface of the sea. The results of the research are shown in Figure 7.

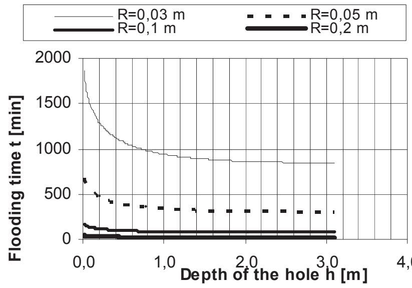

Fig. 7. Flooding time t_f for the engine room

Figure 7 presents that t_f for the compartment with dimension of damage R=0,2m, placed 3 m below the surface of the sea, equals 3,4 minutes. This time is too short to seal the damage. Consequently, further activities of crew should be directed to protect spreading the water covering interior of the ship and to strengthen the construction of the watertight bulkhead.

THE METACENTRIC HEIGHT CALCULATION

The next part of the research was devoted to estimate a metacentric height while flooding a damaged compartment. To calculate this parameter the added mass method was used. The result of calculations is shown in Figure 8.

To calculate the metacentric height the free surface effect was taken into consideration. Figure 9 implies that in the early stage of flooding the compartment, the metacentric height GupMu, is less than GM. In the later stages, GupMu increases and improves stability of a ship. This situation takes place due to adding a mass in the lower part of the ship.

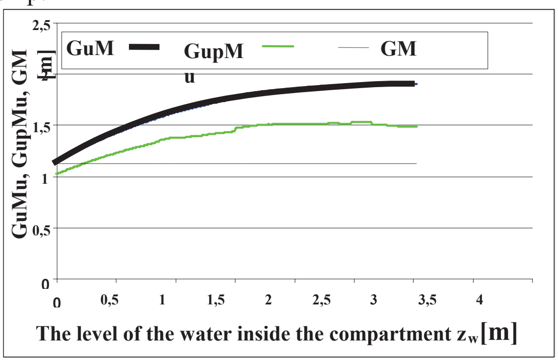

Fig. 8. Metacentric height (GM- initial metacentric height (before demage); GuMu- metacentric height while flooding engine room; GupMu- metacentric height while flooding engine room with free surface.

CONCLUSIONS

The knowledge of the time t_f and metacentric height allows a commanding officer to make decisions while fighting for survivability of the ship.

The method of determining the permeability presented in the paper enables us to make calculating the time t_f more accurate.

The modified method can be used to calculate the time t_f for ship type 888 with different types of hull damages. The method can be adopted for some other type of warships.

Computer visualisation of flooding process damaged compartments and ship position can be a base to define general rules to make proper decisions during the process of damage control.

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