COMPARATIVE ANALYSIS OF THE FLOODING TIME MAIN ENGINE SHIP TYPE 888 DEFINED FROM CALCULATIONS AND MODEL RESEARCH

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Abstract

Research on damage stability and invincibility 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) is one of the key elements which have influence on a rescue action. The knowledge of the time mentioned is very important for a commanding officer making decisions while fighting for invincibility and survival of the ship. To provide the information about the time t_f of a ship type 888 a new method was designed. The method was tested experimentally and results of the tests are presented in the paper. In the experiments, the flooding process of compartments was simulated. The flooding time calculation of damaged compartment, according to the method described in the paper, is verified on the laboratory stand bed. Thanks to a suitable construction and new concepts applied for the station, research on the ship reaction and position in the failure situations is possible. The next part of research was carried out on the laboratory stand bed, where the flooding time of damaged compartment of warship model was measured. The results of the experiments can be a base to define general rules to make proper decisions during the process of damage control.

Keywords: *stability and invincibility of a warship model, laboratory stand bed, damage compartment*

1. 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.

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 mistakes or wrong manoeuvrability represent a group of ship accidents and breakdowns which can lead to dangerous lost of floating 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 year. The data mentioned are presented in Fig. 1 [4].

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, sinkability and maneuverability of the ship.

Exercises within the confines of the process of damage control, apart from construction solutions, increase the safety of both a ship and crew. Training is carried out in well prepared training centres

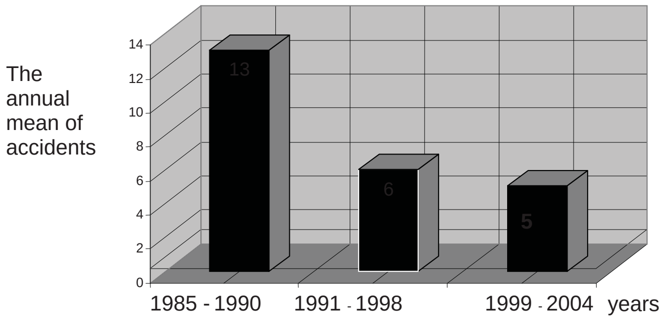

Fig. 1. The overall structure of accidents and breakdowns between 1985 and 2004

which are situated in the United Kingdom, Germany, Netherlands and Pakistan. The centres 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 parameter: t_f for the ship type 888. Presently, there is used only simplified method to calculate parameters above. The method presented in the paper has a distinctive difference compared to the existing, similar methods talk in some publications. The worked out method presents the permeability value depended on the water level inside the damaged compartment. Due to this, we can estimate more accurate quantity of the water in the compartment and finally more accurate the flooding time damaged compartment. The aim of presented method is to provide experimental validation. The information about t_f 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 invincibility is senseless and when all effort should be directed to save the crew and documents [6].

2. The calculating the time of flooding ship's compartment

When calculating t_f, first, the velocity of water running through the damaged hull has to be determined. The water flowing through a hole can be compared to liquid flowing from a tank of a surface A. The water velocity can be obtained according to Torricelli's formula [9]:

$$v_w = \sqrt{2 \cdot g \cdot h}\,, \tag{1}$$

where h - depth of a hole.

For the real liquid the formula (1) can be presented as follows [9]:

$$v_w = \varphi \cdot \sqrt{2 \cdot g \cdot h}\,, \tag{2}$$

where φ = 0.97-0.98 - the velocity coefficient dependant on the kind of liquid.

The equation (3) is applied when the water surface inside a hull is below a lower edge of a hole, i.e. for a constant pressure of the water. When the water pressure is changeable (the water surface inside a hull is above an edge of a hole and still grows up) the velocity of the water flowing to the compartment can be obtained according to the formula [9]:

$$v_w = \varphi \cdot \sqrt{2 \cdot g \cdot (h - h_0)}\,, \tag{3}$$

where h_0 - height of liquid inside a tank above an edge of a hole.

The hole in the body can have a different shape and dimension dependant on the reason of damage. The shape of the hole influences a quantity Q of the water flowing to the compartment. The quantity Q depends on ν, which in turn is a product of coefficient φ and narrowing coefficient χ = 0.61-0.64 [10]. Therefore, the quantity of water Q flooded to the interior compartment can be obtained from the formula [9]:

$$Q = A_0 \cdot v \cdot \sqrt{2 \cdot g \cdot (h - h_0)}\,. \tag{4}$$

The time t_f is as follows [9]:

$$t_f = \frac{V}{Q}\,. \tag{5}$$

where V - the volume of the water inside a compartment.

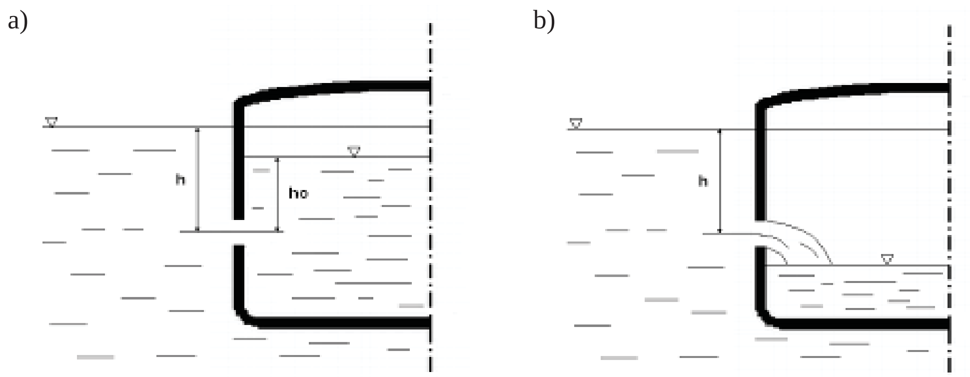

Fig. 2. Compartment being flooded: a) with constant water pressure, b) with variable water pressure

3. Calculating the volume of damage compartment

The calculation of t_f was conducted for a damaged engine room of the ship type 888. The computer program was built to enable the calculations above. The program makes it possible to fix basic and necessary parameters to make a correct evaluation of the state of a ship. In turn, the information about the parameters mentioned above makes it possible to take proper decisions during the process of the damage control.

3.1. Computing the volume of damaged compartments

The volume of a damaged compartment is necessary to calculate the time t_f. The lines plan of the ship's hull is used to compute the theoretical volume v_t. 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 Fig. 3 [5].

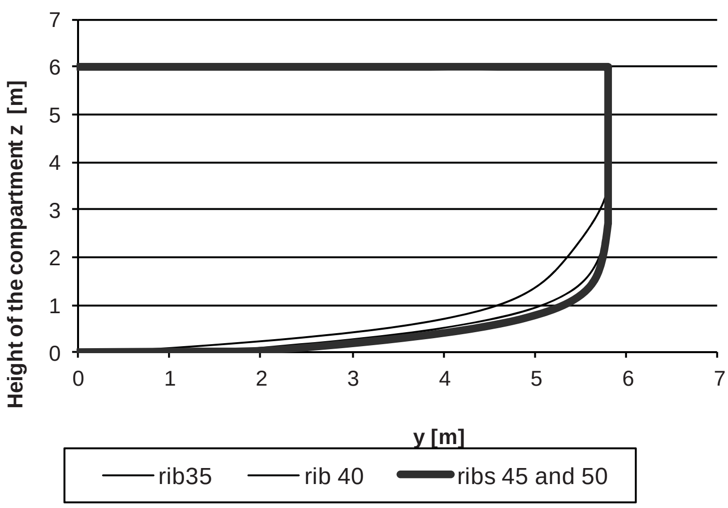

Fig. 3. Sections of engine room

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 Fig. 4.

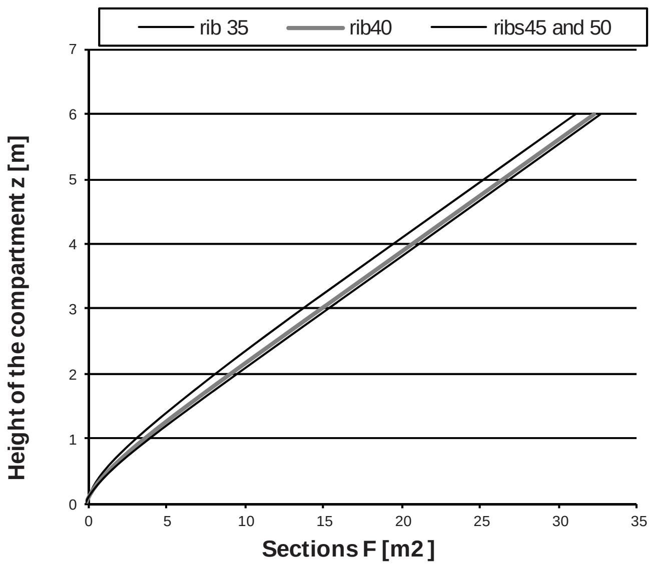

Fig. 4. Integral curve engine room sectional areas

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

$$v_t = \sum \frac{(F_i + F_{i+1}) \cdot l_w}{2}, \tag{8}$$

where l_w - the distance between sectional areas, and F_i, F_{i+1} - section areas.

3.2. 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) has being occupied by machinery, cargo, accommodation spaces, etc. The value of permeability for compartment is calculated by the formula [1]:

$$\mu = \frac{v}{v_t}, \tag{9}$$

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 engine room was estimated. Its value depends on the height of the water inside the compartment. The graph of the permeability is shown in Fig. 5 [5].

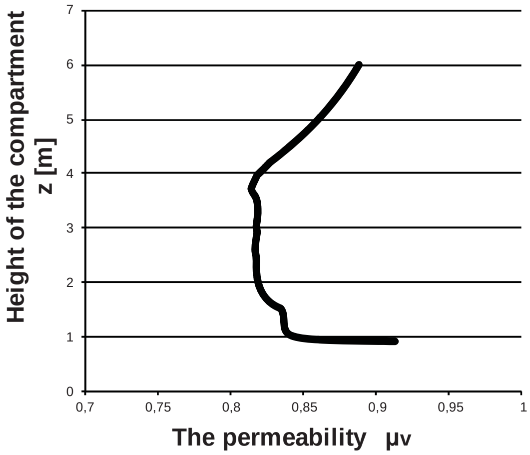

Fig. 5. Graph of the engine room permeability μ_v

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.

3.3. Simulation for damaged compartment

The simulation model of the engine room, equipped with all main mechanisms and devices, was made in the next part of the research. The view of the compartments being flooded is shown in Fig. 6 [5].

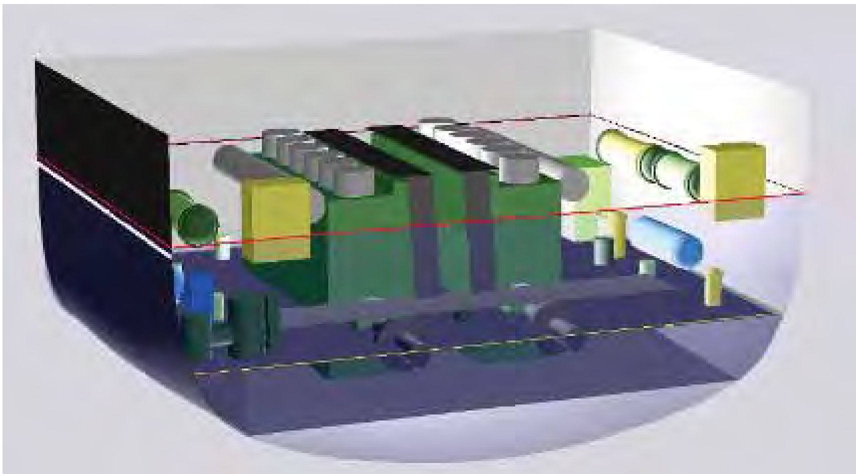

Fig. 6. Engine room compartments being flooded

4. The analysis of the influence of damage parameters on the time 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 dimension of damage were taken into consideration.

In the first stage of the research, t_f for the engine room was fixed. 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 0.1 m to 3.0 m below the surface of the sea. The results of the research are shown in Fig. 7.

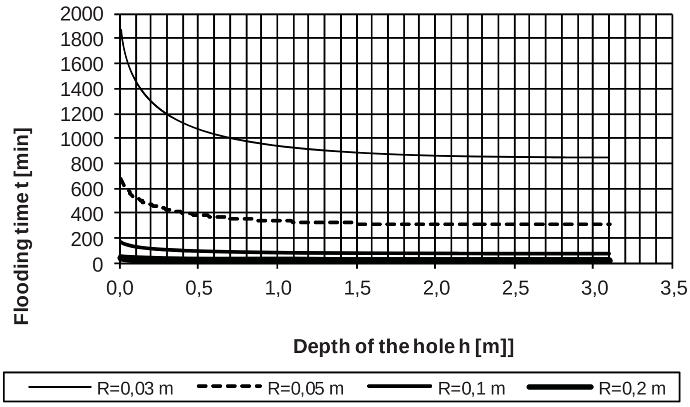

Fig. 7. Flooding time t_f for the engine room

Figure 7 presents that t_f for the compartment with dimension of damage R = 0.2 m, 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.

5. The preliminary research on the flooding time on the laboratory stand bed

The flooding time calculation of damaged compartment, according to the method described in the paper, is verified on the laboratory stand bed. Thanks to a suitable construction and new concepts applied for the station, research on the ship reaction and position in the failure situations is possible. The main object of laboratory stand bed is ship's model type 888. The hull of model was made in accordance with the body plan. The elements of the superstructure and the ship equipment were simplified in the model but the appropriate scale 1:50 was kept. Main dimensions of the model are: length L-1.5 m breadth B-0.25 m and draught T-0.08 m. This model is set up with specialized devices used for measurement of the position and for the analysis of the ship reaction during simulated damages. The shape of the model is shown in Fig. 8 [8].

The invincibility research of the ship's model after having damaged one or more compartments will enable us to assess the flooding time of the model compartments and even whole model as well.

Fig. 8. The laboratory stand bed

The engine room compartment was chosen to simulate. The compartment damage simulation can be done by opening the suitable valve situated inside the model. The scheme of the ship's model with a damaged compartment is shown in the computer window and presented in the Fig. 9 [8].

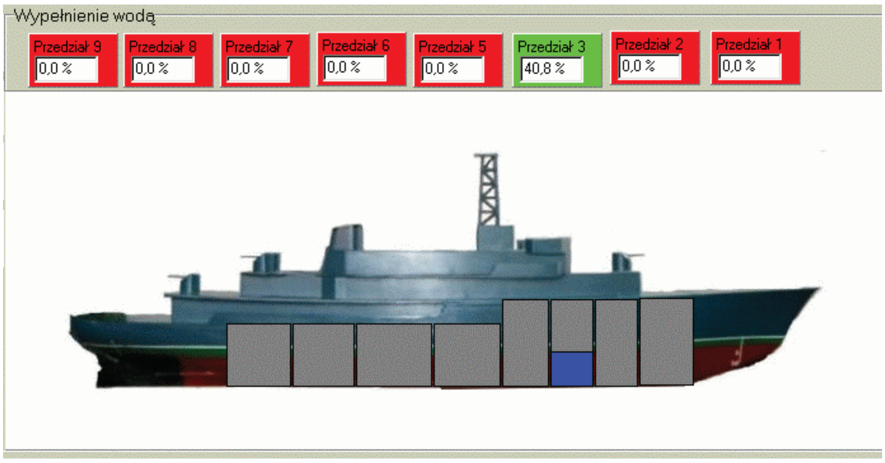

Fig. 9. The scheme of ship's model with a partially flooded compartment

Within the framework of model research, the time of flooding the engine room of 888 type of vessel was determined. The research consisted in determination of time that will have passed from opening of the valve, making it possible to flood the compartment, until the outboard water level levelled with the liquid level in the compartment. The research was carried out using a sensor of water level in the compartment (pressure sensor) and a stopwatch. During the measurement two parameters were registered, i.e.:

- level of liquid in the compartment,
- flooding time.

Analysis of the performed measurement showed that level of the liquid in the compartment was approaching to 0.088 [m] of the liquid column and fixed itself after approximately 33 [min]. Knowing the scale of the model the real object's compartment flooding time assumed 2h45'. The flooding time obtained from the calculations was 1h59'. The compartment flooding time calculations were carried out for the leakage radius r = 0.08 [m]. What was observed as a result of the research was a difference in the compartment flooding time at the level of 30%. The difference can be affected by, for example, imprecise physical model of the engine room. The computer model of engine room, which is used for flooding time calculation, is more accurate than physical model. Due to this, the permeability of damaged compartment of physical model has value different than permeability used by the computer program. Finally, the result of flooding time obtained from calculation is different than from research on the physical model. Presented results are obtained on the basis of experimental preliminary research and in the next step it will be corrected.

6. Conclusion

The knowledge of the time tf allows a commanding officer to make decisions while fighting for invincibility and for the survival of the ship.

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

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

The comparative analysis shows that the flooding time obtained from calculation and from research on the physical model is different at the level of 30% due to imprecise physical model of the engine room.

References

[1] Derett, D. R., *Ship stability for Masters and Mates*, BH, Oxford 2003.
[2] Dudziak, J., *Teoria okrętu*, WM, Gdańsk 2006.
[3] Jakus, B., Korczewski, Z., Mironiuk, W., Szyszka, J., Wróbel, R., *Obrona przeciwawaryjna okrętu*, Naval Academy, Gdynia 2001.
[4] Korczewski, Z., Pawlędzio, A., Wróbel, R., *Analiza ilościowa wypadków i awarii na okrętach Marynarki Wojennej RP w latach 1985-2004*, Przegląd Morski, Nr 2, Gdynia 2005.
[5] Kowalke, O., *Komputerowa symulacja zatapiania przedziału siłowni okrętu typu 888*, AMW, Gdynia 2006.
[6] Miller, D., *Damage control - an insurance policy*, International Defence Review, No. 5, 1994.
[7] Mironiuk, W., Pawlędzio, A., Wróbel, R., *Trenażer do walki z wodą*, Gdynia, pp. 14-30, 2004.
[8] Mironiuk, W., *Preliminary research on stability of warship models*, COPPE Brazil, Rio de Janeiro 2006.
[9] Troskolański, A, *Hydromechanika Techniczna*, Warszawa 1961.