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The Influence of the Flooding Damaged Compartment on the Metacentric Height Ship Type 888

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ABSTRACT: Research on damage stability and unsinkability 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 fighting for unsinkability and survival of the ship. To provide the information about the time t_f 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 in a ship of the type 888 was simulated. The results of the experiments can be a base to define general rules to make proper decisions during the process of damage control.

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 maneuverability 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 Figure 1. (Korczewski & Wróbel, 2005).

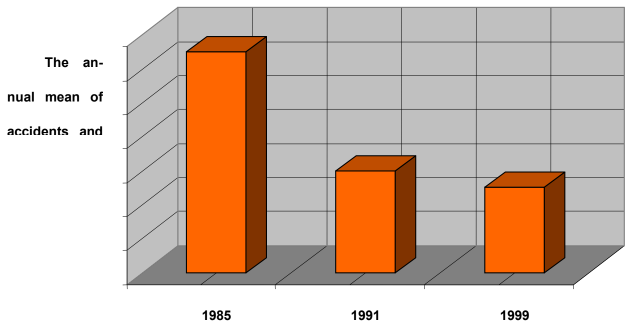


Figure 1. The overall structure of accidents and breakdowns between 1985- 2004

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, 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. 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.

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 unsinkability is senseless and when all effort should be directed to save the crew and documents (Miller, 1994).

2 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 from the following formula (Troskolanski 1961):

$$v_w = \sqrt{\frac{2 \cdot g \cdot h_z}{1 - \left(\frac{A_0}{A}\right)^2}} \tag{1}$$

where A_0=cross section of a hole; A = horizontal cross section of a tank; g = acceleration due to gravity, and h_z = height of a liquid inside the tank.

Because the surface of a hole is much smaller than a sea surface, the water velocity can be obtained according to Torricelli's formula (Troskolanski 1961):

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

where h = depth of a hole.

For the real liquid the formula (2) can be presented as follows (Troskolanski 1961):

$$v_w = \varphi \cdot \sqrt{2 \cdot g \cdot h} \tag{3}$$

where $\varphi = 0{,}97 \div 0{,}98$ - 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 (Troskolanski 1961):

$$v_w = \varphi \cdot \sqrt{2 \cdot g \cdot (h - h_0)} \tag{4}$$

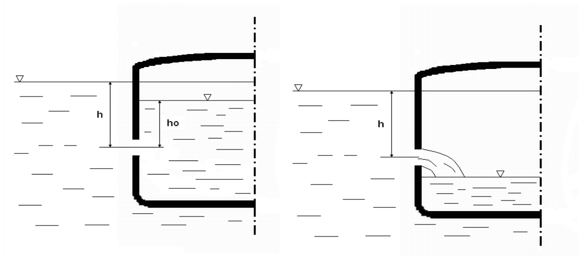
where h_0 = height of liquid inside a tank above an edge of a hole.

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 $\chi = 0{,}61 \div 0{,}64$ (Troskolanski 1961). Therefore, the quantity of water Q flooded to the interior compartment can be obtained from the formula (Troskolanski 1961):

$$Q = A_0 \cdot \nu \cdot \sqrt{2 \cdot g \cdot h} \tag{5}$$

When the pressure of the water is changeable the quantity of water Q inside the compartment is calculated from the formula (Troskolanski 1961):

$$Q = A_0 \cdot \nu \cdot \sqrt{2 \cdot g \cdot (h - h_0)} \tag{6}$$



a) b)

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

The time t_f is as follows (Troskolanski 1961):

$$t_f = \frac{V}{Q} \tag{7}$$

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

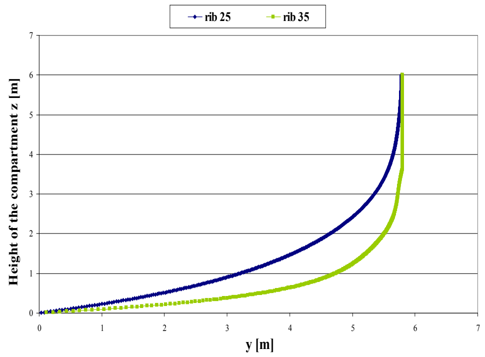
3 CALCULATING THE VOLUME OF DAMAGED COMPARTMENTS

The calculation of t_f was conducted for a damaged engine room and auxiliary power plant of the ship type 888. To enable the calculations above simulating computer program was built. The program made 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 make extracted sections on ribs number 25, 30, 35, 40, 45, 50 of the damaged compartment. The sections are shown in Figure 3 (Tarnowski 2008, Kowalke 2006).

a)



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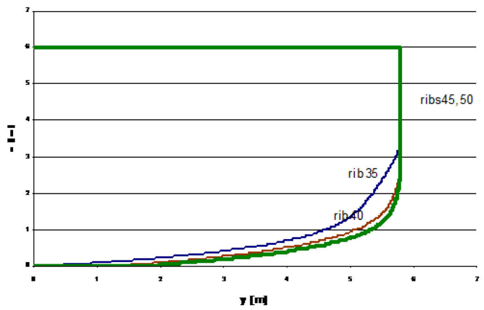
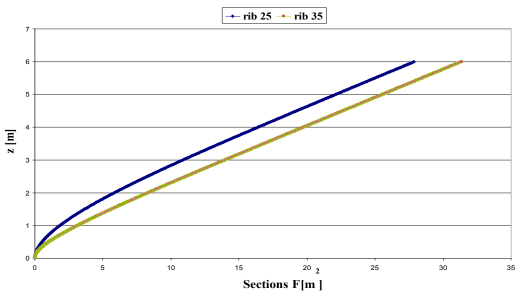


Figure 3. Sections of compartments:
a) auxiliary power plant,
b) engine room.

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)



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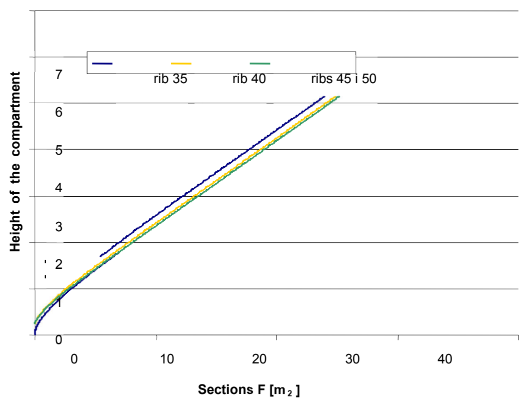


Figure 4. Integral curve sectional areas:
a) auxiliary power plan;
b) engine room.

Using section areas and a distance between them, the theoretical compartment volume v_t can be calculated, by the formula (Deret 2003, Dudziak 2006):

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

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

3.2 *The permeabilities calculation*

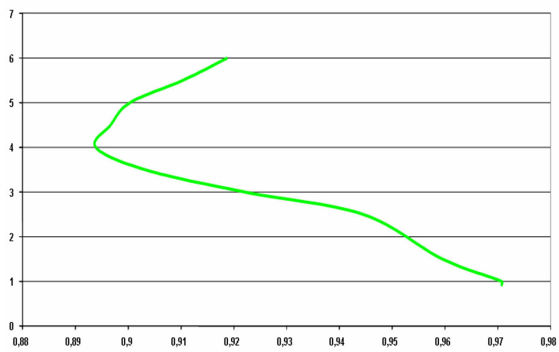
The volume of the empty compartment was calculated by means of the computer program. The real quantity of the water, flooding the compartment, is less than the theoretical volume of the compartment due to the volume of all mechanisms and devices inside the compartment. Usually, to calculate a real quantity of the water, the permeability of flooding compartment μ is used. The values of permeabilities for two compartments are calculated by the formula (Deret 2003):

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

where v_t = theoretical compartment volume; v - real quantity of the water inside the compartment.

The numerical value of the permeabilities 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. In preliminary research, permeabilities of both, the auxiliary power plant and the engine room were estimated. Their value depends on the height of the water inside the compartment. The graph of the permeabilities is shown in Figure 5 (Tarnowski 2008, Kowalke 2006).

a)



Permeability μ_v

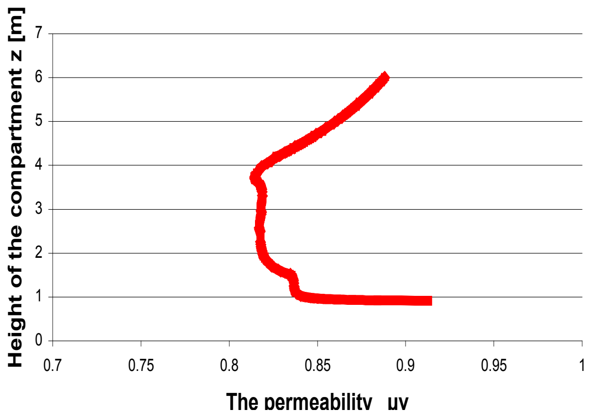


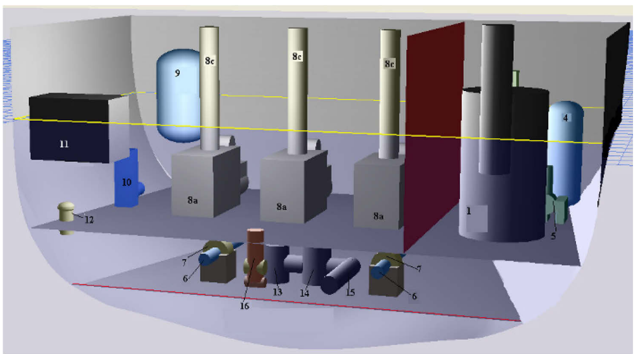
Figure 5. Graph of the permeability μ_v :
a) auxiliary power plant,
b) engine room.

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 0,85.

3.3 *The model of simulation for damaged compartment*

The simulation model of the auxiliary power plant and 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 Figure 6 (Tarnowski 2008, Kowalke 2006).

a)



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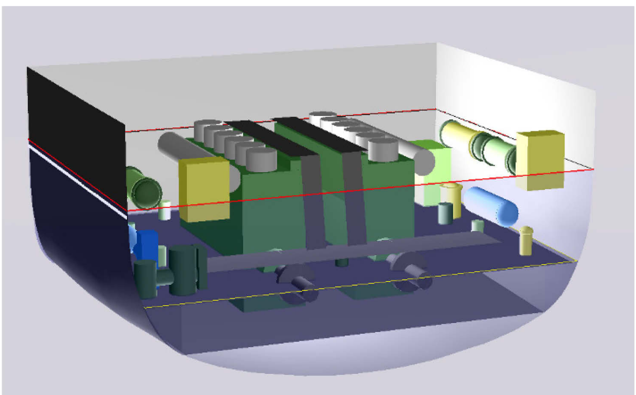

Figure 6. Compartments being flooded:
a) auxiliary power plant,
b) engine room.

4 THE ANALYSIS OF THE INFLUENCE OF DAMAGE PARAMETERS ON THE TIME t_f FOR THE COMPARTMENTS SHIP TYPE 888

The experimental research on t_f for the auxiliary power plant and the 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 auxiliary power plant was fixed. The calculations of t_f were made for the following example conditions: ship's draught T=4m, the dimension of damages 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 6.

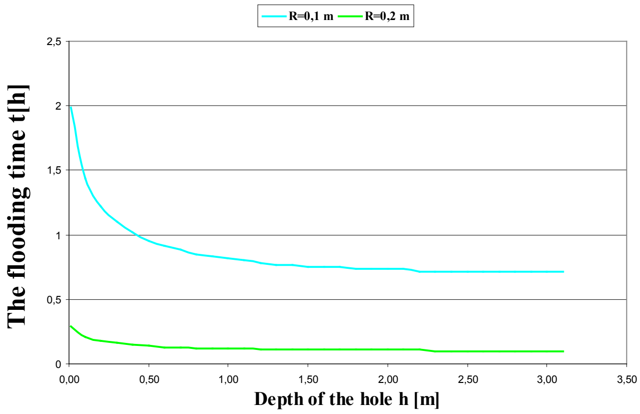

Figure 6. t_f for auxiliary power plant

In the next step, t_f for the engine room was calculated. The results of the research are shown in Figure 7.

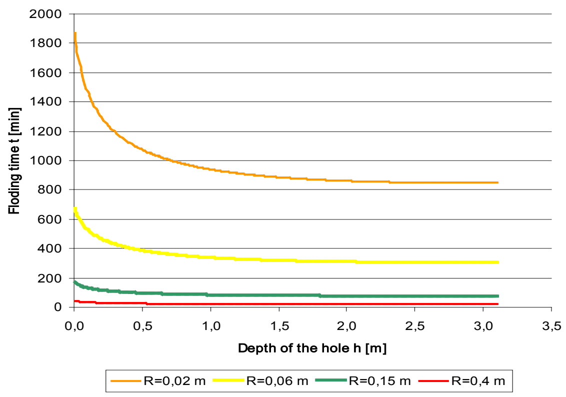

Figure 7. t_f for engine room

Figure 7 presents that t_f for the compartment with dimension of damage R=0,4m, 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 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 10.

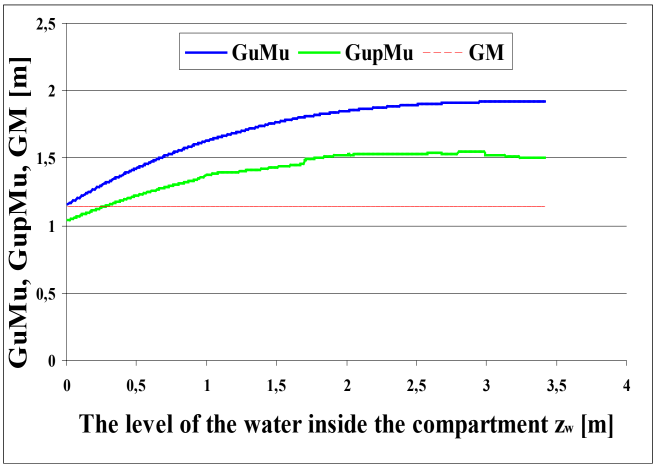

Figure10. Metacentric height
GM- initial metacentric height (before demage);
GuMu- metacentric height while flooding engine room;
GupMu- metacentric height while flooding engine room with free surface.

To calculate the metacentric height the free surface effect was taken into consideration. Figure 10 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.

6 CONCLUSIONS

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

The time t_f depends on both the dimension and the place of a damage.

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

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 different type of warships.

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