THE RESEARCH ON THE FLOODING TIME AND STABILITY PARAMETER OF THE WARSHIP AFTER COMPARTMENTS DAMAGE

Waldemar Mironiuk, Naval Academy, Poland

ABSTRACT

Research on damage stability and unsinkability establishes the source of the knowledge according to a ship reaction after flooding its compartments. A short description of Polish warships' accidents and damages which took place in 1985-2004 was presented in the paper. The flooding time of the damaged compartments and stability parameters are one of the basic parameters which have influence on the rescue action. Knowledge of the flooding time compartments and a metacentric height are very important for the commanding officer making decisions while fighting for unsinkability and survival of the ship. The computational method was designed to provide information about possibility of calculation the flooding time of damaged watertight compartments. The analysis of calculated results was made and described. On the basic of the built computer program, a simulation of the flooding process of the damaged compartment ship's type 888 was shown. 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. Results of both, calculated and measured scores were compared in the paper. Results received from research can be basic information to make a decision to carry out a proper action of damage control.

Keywords: *stability and unsinkability of a warship model, laboratory stand bed, flooding time, damage*

1. INTRODUCTION

Naval experiences show that even highly organized fleets struggle against accidents and technical breakdowns which couldn't be completely eliminated. Breakdowns of ship's technical equipment can be classified according to the occurrence of the following causes: the impact of enemies warfare agents, materials' defects and defects within the production process, constructional defects, technological defects in the process of renovation, excessive natural process of material's wear and tear, not fulfilling the requirements for operation and service of equipment, not taking security measures while storing dangerous cargoes e.g. explosive materials, petroleum products and other chemical components of serious fire hazard.

During warfare or even daily ship operation there may happen partial or total loss in functioning mechanisms and installations, in a work - the occurrence of breakdowns.

Failures which are caused by navigational mistakes or maneuverability represent the group of ship accidents and breakdowns which case a dangerous of lost floating of the ship due to flooding the compartment.

Statistical data prepared by the Polish Navy Commission of Warship Accidents and Breakdowns reveal that between years 1985 – 2004 there have been recorded 156 warship accidents and breakdowns. Their overall structure examined in certain periods, taking into account the annual mean, is presented in Figure1 (Korczewski & Wróbel, 2005).

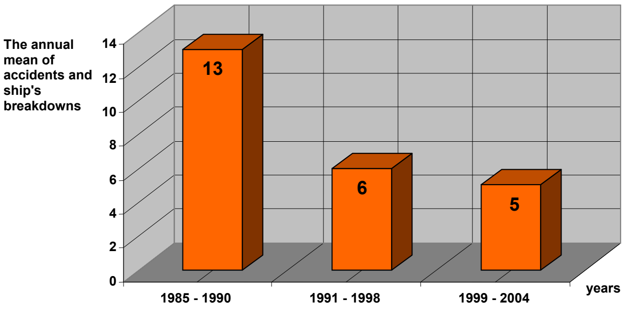


Figure 1. The overall structure of accidents and ship's breakdowns between 1985 - 2004

In such a situation the crew activities decide about fighting ability of a warship and should be directed to carry out a proper action of damage control and protect a stability, sinkability and manoeuvre of the ship.

The action which increases the safety of both a ship and a crew, apart from construction solutions, is training in damage control exercises. Training is carried out in well prepared training centres. These centres have ship models designed for the simulation of failure states which occur most frequently while operating a ship. Investigating the phenomenon during break-down as assess a flooding time a compartment is one of the research aims.

Information about flooding time is very important for a commanding officer. It enables him to carry out a proper action of damage control. Therefore, the commanding officer - on the basis of the situation assessment - should determine the time, when further fighting for unsinkability is senseless and should direct all the efforts to save the crew and documents (Miller, 1994).

2. THE FLOODING TIME SHIP'S COMPARTMENT CALCULATION

The first stage of the flooding compartment time calculation is assessing the water velocity flooding through the damaged hull. Water flowing through the hole can be compared to the established flowing liquid phenomenon from the tank with a free surface A. Then, the water velocity can be obtained from the mathematic formula (Troskolanski 1961):

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

A_0 - a cross section of a hole,

A – a horizontal cross section of a tank ,

g – an acceleration due to gravity,

h_z - a high of a liquid inside the tank.

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

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

h - a depth of the hole.

For the real liquid the formula is equaled (Troskolanski 1961):

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

$\varphi = 0{,}97 \div 0{,}98$ - the velocity coefficient depended on the kind of liquid.

This equation is applied when the water surface inside the hull is below the lower edge of the hole. It means a constant pressure of the water. When the water pressure is changeable (the water surface inside the hull is above the edge of the hull and steel grow up) the velocity of the water flooding to the compartment can be obtained according to the formula (Troskolanski 1961):

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

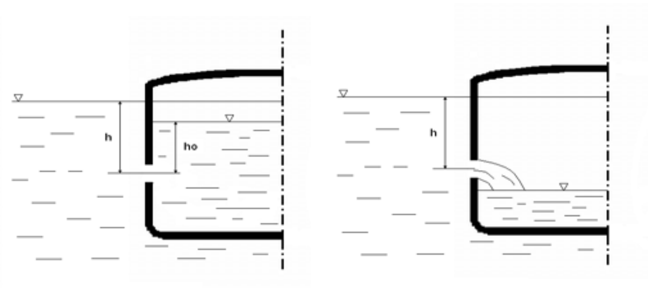
h_0 - a high of liquid inside the tank above the edge of the hole.

The hole of the body can have a different shape and dimension depended on the reason of damage. The influence of the damaged shape on the quantity of the water flooding to the compartment Q is applied by the narrowing coefficient $\chi = 0{,}61 \div 0{,}64$ (Troskolanski 1961). The product of coefficients φ and χ, marked ν, depends on the shape of the hole. Therefore, the quantity of water, which will flood 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 water pressure is changeable the quantity of water 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. Flooding the compartment:
a) with constant water pressure,
b) with changeable water pressure.

The flooding time of ship's compartment is obtained (Troskolanski 1961):

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

V- the volume of the water inside the compartment.

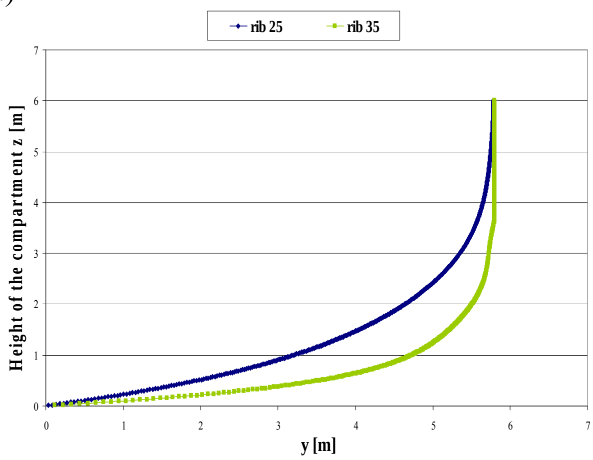
3. THE CALCULATION OF THE VOLUME DAMAGED COMPARTMENTS

The computation of the flooding time of the compartment was conducted for the damaged engine room and auxiliary power plant of the ship type 888. The computer and a simulate program of the flooding process of the damaged compartment was built. Thanks to those programs, basic and necessary parameters to make a correct assessment of the ship's state after damage enable us to carry out a proper action of damage control.

3.1. The volume of damaged compartments computation

The damaged compartment volume is necessary to calculate the flooding time of the compartment. The lines plan of the ship's hull are supplied to computation the theoretical compartment volume v_t. On the basic of the lines plan, extracted sections on ribs number 25, 30, 35, 40, 45, 50 of the damaged compartment were made. Sections are shown in Fig.3 (Tarnowski 2008 & Kowalke 2006).

a)



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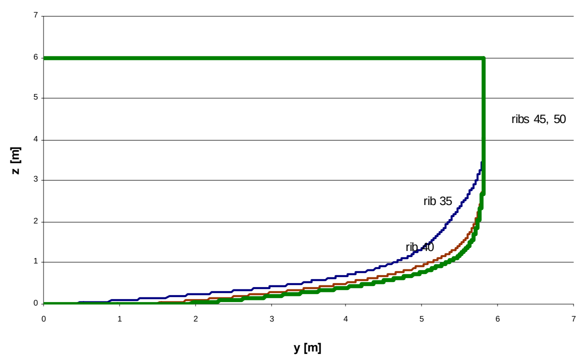
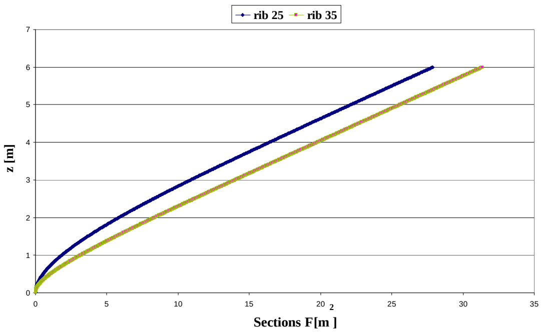


Figure 3. Sections of compartments:
a) the auxiliary power plant,
b) the engine room.

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

a)



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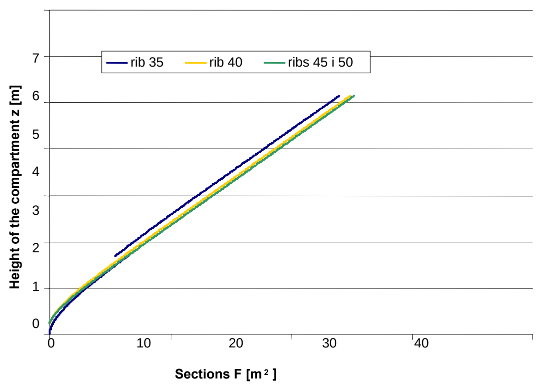


Figure 4. The integral curve sectional areas: a) the auxiliary power plan; b) the engine room.

Knowing section areas and a distance between them, the theoretical compartment volume v_t can be calculated, by the formula (Deret 2003 & Dudziak 2007):

$$v_t = \sum \frac{(F_i + F_{i+1}) \cdot l_w}{2} \tag{9}$$

l_w - the distance between sectional areas,

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

3.2. The permeabilities calculation

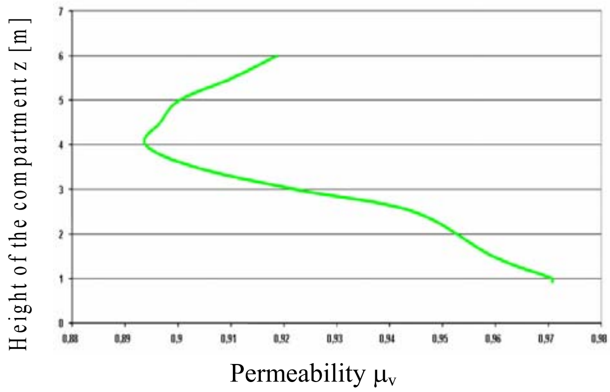
The volume of the empty compartment was obtained as a result of a carried out calculation following the computer program. The real quantity of water, flooding the compartment, is less than theoretical volume of compartment due to volume of all mechanisms and devices inside it. Hence, the real quantity of the water flooding the compartment is less than theoretical volume of compartment. Usually, to calculate a real quantity of the water, the permeabilities of flooding compartments marked as μ are used. The value of them are calculated as a formula (Deret 2003):

$$\mu = \frac{v}{v_t} \tag{8}$$

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

a)



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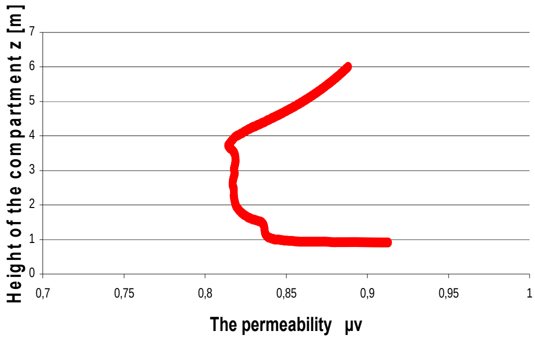


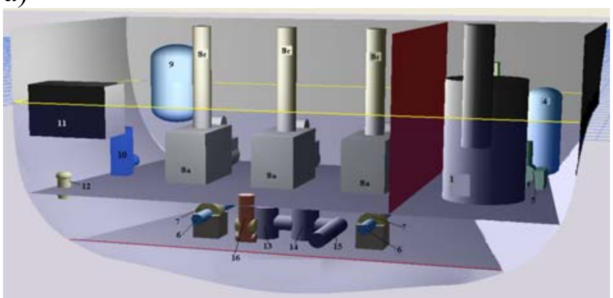
Figure 5. The graph of the permeability μ_v : a) the auxiliary power plant, b) the engine room.

The average value of the permeability for chosen compartments, obtained on the basic of research, is comparable with the value of the SOLAS Convention, which equals 0,85.

3.3. The simulation model damaged compartment

The simulation model of the auxiliary power plant and engine room, equipped with all main mechanisms and devices, was made in the next part of research. The view of the flooding compartments is shown in Fig.6 (Tarnowski 2008 & Kowalke 2006).

a)



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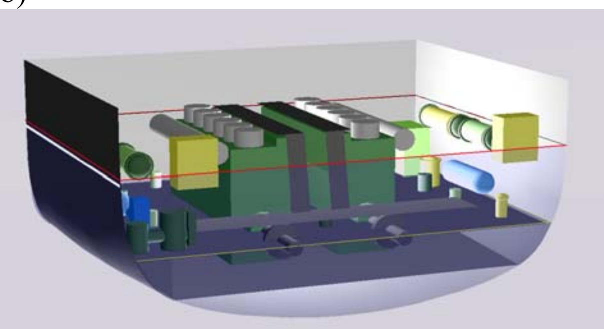

Figure 6. The view of the partial flooding compartments:

a) auxiliary power plant,
b) engine room.

4. THE ANALYSIS OF INFLUENCE DAMAGE PARAMETERS ON THE FLOODING TIME OF THE COMPARTMENTS SHIP TYPE 888

The experimental research on the flooding time of the auxiliary power plant and the engine room ship's type 888 was led for the different parameters of damages. During the research, the place and the dimension of damage were taken into consideration.

In the first stage of the research, the flooding time of the auxiliary power plant was carried out. For example a calculation of the flooding time was made for ship's draught equaled T=4m, the dimension of damages with the radiuses R=0,1 m and R=0,2 m. The holes were placed from 0,1m to 3,0 m below the sea water surface. The results of the research are shown as a graph form in Fig.6.

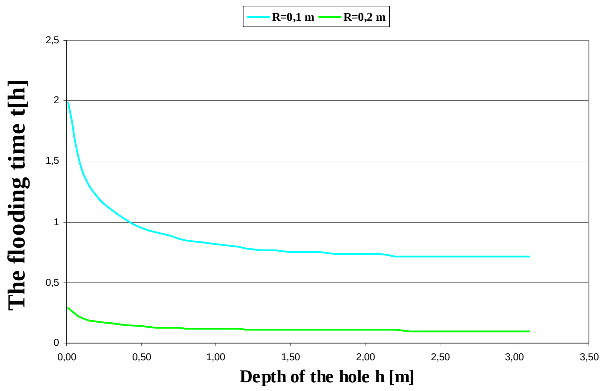

Figure 6. The graph of the auxiliary power plant flooding time.

In the next step the flooding time of engine room was calculated. The results of the research are shown as a graph form in Fig.7.

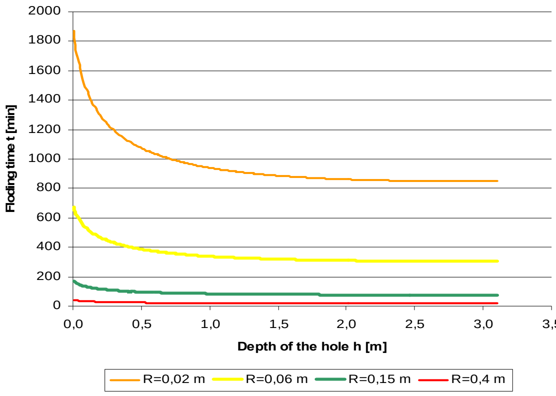

Figure 7. The graph of the engine room flooding time.

From curves presented in Fig.7 we can notice that the flooding time of the compartment for damage with dimension equals R=0,4m placed 3 m below a sea water surface equals 3,4 minutes. This time is as short that the fighting for unsinkability is senseless and a crew should leave the damaged compartment and direct all the efforts to protect spreading water covering the ship and strengthen the construction of the watertight bulkhead.

5. THE RESEARCH ON THE FLOODING TIME ON THE STAND BAD

The calculating the flooding time of damaged compartment, according to the method described in the paper, is verified on the laboratory stand bad. 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 ship's model type 888 is the main object of research because it 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 (Mironiuk 2006).

The unsinkability research on the ship's model after damaging one or more compartments will enable us to assess the flooding time of the model compartments and a even whole model as well.

Figure 8. The laboratory stand bad.

The engine room compartment was chosen to the simulation. 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 presented in the Figure 9 (Mironiuk 2006).

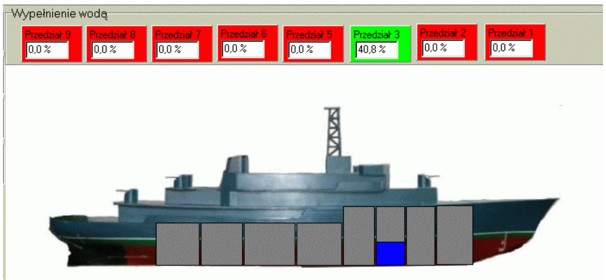

Figure 9. The scheme of ship's model with partially flooded a compartment.

The compartment flooding time of the model obtained on the basis of research on the stand bad is compared to the flooding time calculated from mathematical formulas. The difference between measured and calculated parameter equals about 20 % and can be affected of by imprecise model of engine room.

6. THE METACENTRIC HEIGHT CALCULATION

The next part of research on was estimating a stability parameter a metacentric height while flooding a damaged compartment. To calculate this parameter the method of added mass was used. The result of the calculation is shown as a graph form in figure 10.

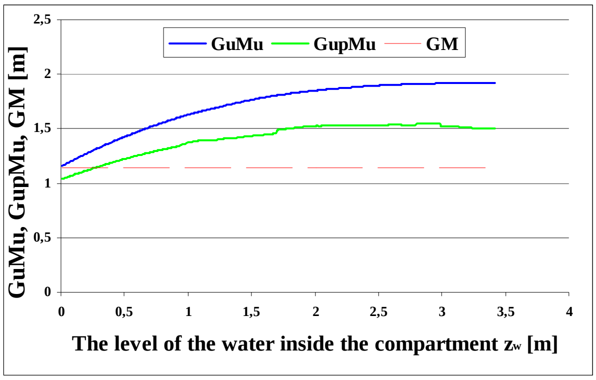

Figure 10. the graph of the metacentric height GM- beginning metacentric height; GuMu- the metacentric height while flooding the engine room; GupMu- the metacentric height while flooding the engine room with free surface.

During the calculation the free surface effect was respected on the ship with damaged compartment. From the graph of the metacentric height, shown in fig.10, we can notice that in the early stage of flooding the compartment the stability parameter like the metacentric height GupMu, with respect of free surface effect, was value less then beginning. This situation takes place due to adding a mass in the lower part of the ship. In the later stage of flooding the compartment GupMu increases and improve bigger value.

7. CONCLUSIONS

The presented method of the permeability determination enables us appointing its value depended on the water level inside the compartment.

The flooding time damaged compartment depends on not only the dimension but the place of damage as well.

Knowledge of the flooding time compartment lets a commanding officer to make decisions while fighting for unsinkability and for the survival of the ship.

The compiled method can be abused to calculate the flooding time of damaged compartments ship's type 888 depended on the damaged ship's hull parameters. This method can be adopted for different type of warships.

The real measurement flooding time of engine room compartment of the model ship's type 888 in comparison with the flooding time received from the calculation method is different, so the model of the ship compartment should be corrected.

Taking into consideration the safety of the ship while flooding damaged compartment knowlage the value of the stability parameter like the metacentric height with free surface effect is very important especially in the early stage.

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