Preliminary Research on Stability of Warship Models

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ABSTRACT

In the paper a description of the stability and unsinkability of the navy ships in a laboratory stand bed- designed and built in the Naval University of Gdynia- has been presented. Some scores of preliminary research of warship's model stability have been presented as well.

The range of research and training of crew can include static and dynamic stability. The presented laboratory offers a possibility not only to analyse the influence of free water surface effect in the compartments or tanks but also to analyse the influence of taking on, moving and removing loads on the initial stability of the ship. Experience acquired in the research station can lead to a better phenomenon recognition occurring in the everyday ship operations and cause increasing of sailing safety.

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

1. INTRODUCTION

A warship is a complex technical system whose reliability influences fighting ability (Mironiuk & Wróbel, 2004). However, as the literature analysis and maritime experience point out, even perfectly organised war fleets have to deal with accidents and ship failures. These can pose a threat to the health of a ship's crew and lead to death. In the complex international situation ship damages caused by enemy fighting means (rockets, mines, bombs, explosives) are more and more frequent. A good example is the ship USS STARK (FF0 —31) which was hit by two rockets in 1987 on the waters of the Persian Gulf (35 victims). USS SAMUEL B. ROBERTS (FF0 —58) which operated on the water of the Persian Gulf in 1988 touched the mine and sustained heavy damages. Another example is a destroyer DDG 67 USS COLE which became an aim of the terrorist attack in Yemen in October 2000 (17 killed and 12 injured) (Korczewski & Wróbel, 2005).

There are plenty of examples, but the most important thing in such a situation is to make a correct assessment of the ship's state after a damage, which enables us to carry out a proper action of damage control. It is obvious that firm determination of the states of a ship after damage is impossible, all the more, a state of the sea has a great influence on an act of sinking. Therefore, a commanding officer (making decisions while fighting for unsinkability and for the survival of the ship) should assess the state of the ship after an accident, making use of his own experience and taking all the circumstances into account. 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).

Today, many countries start to pay more and more attention to improving the damage control elements. 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 which are situated in the United Kingdom, Germany, Netherlands and Pakistan. 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 is one of the research aims. Research results are used by creators of software, which gives assistance to a crew while making decisions in critical situations. However, there are not many ships witch such programs. Thus the ship's crew must be prepared in early stages of training to face situations which threaten safety of the ship.

On the basis of the analysis of the existing Polish centres which provide training in damage control, we can draw the conclusion that there are not such specialized centres as mentioned above. The tasks in the Polish Navy are more and more complicated and demand well educated officer staff and an entire crew.

Taking didactic aims and needs into account as well as meeting expectations concerning the assessment of stability, unsinkability and sailing safety, the stability and unsinkability research on ship's models has been done. This station gives an opportunity to simulate a few failure situations for damaged and not damaged ship.

2. THE SCHEME OF STABILITY AND UNSINKABILITY OF SHIPS MODELS IN A STAND BED

Research on damage stability and unsinkability establishes the source of the knowledge according to a ship reaction in the different operating states. The big advantage of this research is a possibility of failure simulations in the laboratory

conditions using special models of real objects. Thanks to a suitable construction and new concepts applied for the station shown in Figure 2, it will be possible to research the ship reaction even in the failure situations. This station is designed to develop the skills and habits while: (Mironiuk & Wróbel, 2004)

- assessing and restoring stability in failure situations;
- working out the procedures of moving a ship from shoal;
- determining the gravity centre and centre of buoyancy coordinates while adding, removing and shifting masses on the ship.

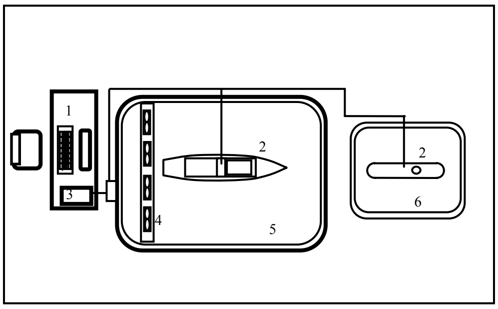

Figure 2. Scheme of damage stability and unsinkability research station for ship models.

1 – manager station,
2 – ship models,
3 – control computer gathering data,
4 – unit of fans,
5 – experimental tank for ship model,
6 – experimental tank for submarine model.

The unsinkability research on the ship's model after damaging one or more compartments will enable us to assess the time of flooding the model compartments and a whole model as well. Moreover, the station gives an opportunity to research the ship model reaction with taking into account influence of the free surface effect. The unit of fans on the experimental tank extends its possibilities for research on a dynamic stability.

3. EQUIPMENT OF THE LABORATORY STAND BED

The main parts of the damage stability and unsinkability research station, on this stage of work, are two warship models: 888 type and

660 type. The hull of each 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 was kept (Mironiuk & Wróbel, 2004).

3.1. The Ship's Model Type 888

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 Figure 3.

Fig. 3. Model of the ship type 888.

The model of the ship type 888 consists of two main parts: the hull made of plastic and superstructure made of plywood protected from moisture. All elements whose area is significant during stability calculations were placed on the decks of the models. Because of the tasks carried out by warships, it is very important to create a ship model designed for simulation of holing. To accomplish this aim, chosen compartments (III, V, VII) were set up with remotely operated valves which enable the simulation of damage shown in Figure 4. These valves allow flooding the compartment to sea surface level. The electromagnetic valves are placed in the compartments with the biggest cubature because these compartments influence unsinkability of the model the most. Another group of valves marked with numbers 4-8 in Figure 4, is designed for flooding the compartments used during the process of righting the ship when the damage is not symmetrically placed. The model of ship 888 was equipped with water system supplied by pumps located outside the model and water level indicator. These indicators mounted in compartments nr III, IV, VII measure the water level on the basis of hydrostatic pressure. An inclinometer mounted on the bow of the model is used for the measurement of the angle of the heel and the trim. The signals received from the indicators are transmitted by a wire to a computer which is equipped with two analog-digital cards and presented on the screen as simple values. Dislocation of main elements of the measurement system is shown in Figure 4.

The indicators and elements placed on the model are connected with the computer by little reduced mass conductors which display the received values on the screen. Taking advantage of a computer, we can carry out the operation of flooding and draining of the chosen compartments. These operations are controlled by a program installed on the computer. The screenshot shown in Figure 5 presents the window of the program.

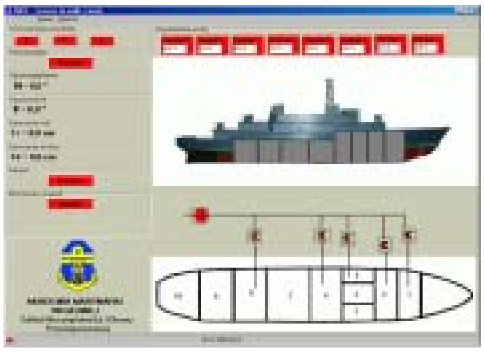

Fig.5. The window of computer program.

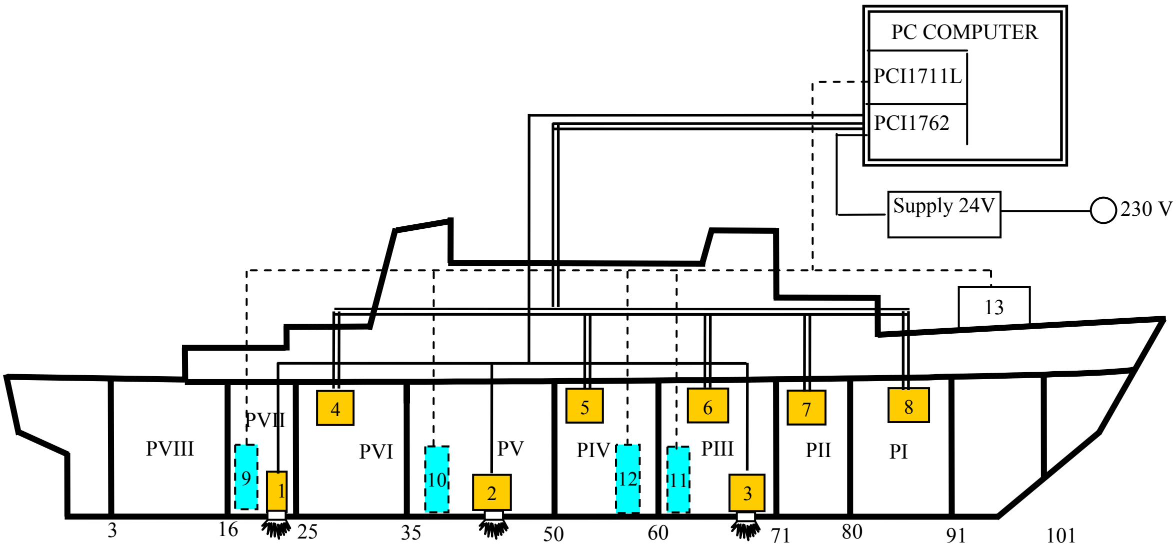

Fig.4. Disposition of elements in the model of ship type 888.

1,2 and 3: Valves for a puncture simulation in the compartment PIII, PV and PVII; 4,5,6,7 and 8: Valves for flooding the compartment PVI, PIV, PIII,PII and PI; 9,10 and 11: Water level indicators in the compartment PVII, PV and PIII; 12: Indicator of ship draught; 13: List indicator.

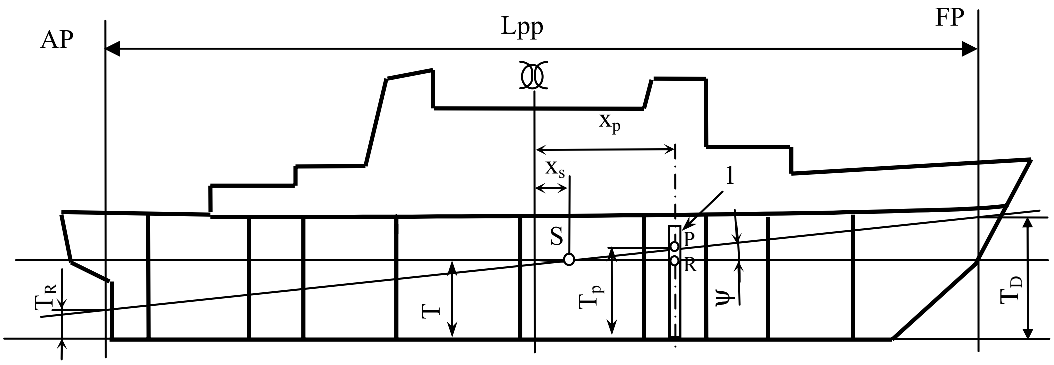

Fig.6. The scheme for calculation bow and stern draught.
1- draught indicator, AP- after perpendicular, FP- forward perpendicular, T- mean draught, Lpp- length between perpendiculars, T_R- after draught, T_D- forward draught, Tp – measured draught, ψ- angle of trim.

The amount of water in the compartment visible in the window program is presented in %. In addition, such parameters of the position as the angle of heel, the angle of trim, bow and stern draught are shown in the real time.

The parameters of bow and stern draught can be obtained in an indirect way. The indicator of mean draught is located near the midship section. Knowing the mean draught and the angle of trim, we can calculate other parameters from mathematical formulas. We take advantage of the scheme presented in Figure 6.

Tangent of the angle trim of a model shown in Figure 6 equals:

$$\mathrm{tg}\,\psi = \frac{\overline{PR}}{x_p - x_s} \qquad (1)$$

The mean draught of the model is found by the formula:

$$T = Tp - \overline{PR} \qquad (2)$$

$\overline{PR}$ - the vertical distance between water-plane and water level within the compartment,

Xp – the distance between draught indicator and midship section,

Xs – longitudinal centre of flotation

We can obtain bow and stern draught from the formula (1):

$$T_D = Tp + \left(\frac{Lpp}{2} - x_p\right)\mathrm{tg}\psi \qquad (3)$$

$$T_R = Tp + \left(-\frac{Lpp}{2} - x_p\right)\mathrm{tg}\psi \qquad (4)$$

Tp – measured draught,
Lpp – length between perpendiculars.

3.2. The Model of Ship Type 660

The research on stability and unsinkability includes numerous issues whose presentation on one model only is impossible. Therefore, the station was provided with a second model of the ship type 660 which is designed to conduct the research, especially from unsinkability domain. The model of this ship is shown in Figure 7.

The model is adapted to flooding the compartments in any way and to any level. On the hull of the model the draught line and draught signs are plotted. Moreover, the position of bulkheads is marked, which helps the user to locate a damaged place.

Fig.7. Model of the ship type 660.

The model of ship type 660 was adapted to the presentation of the problem of influence a free surface effect of the liquid on the stability. In this connection a special superstructure was designed. In its higher part there is a hole used for providing water inside. The water from the high placed compartment can be moved out or moved to the lower watertight compartment. Such operations are carried out while restoring or correcting the stability. In this way it is possible to demonstrate a change of stability after changing the position of the gravity centre and to conduct research on flooding time either of damaged compartments or of the whole model.

3.3. The Model of a Rectangular Pontoon

The process of heaving the ship is very complicated. The best way to recognize this problem is to do some research on a simple object like a rectangular pontoon (Mironiuk & Wróbel, 2003). The construction of a rectangular pontoon model, presented in Figure 8, was designed by a team of workers from the Naval University in Gdynia.

It enables us to carry out the simulation of many states and critical situations which can occur on the ship. The dimensions of the construction and its mass were selected in order to use it for doing research and exercises relating to many more domains.

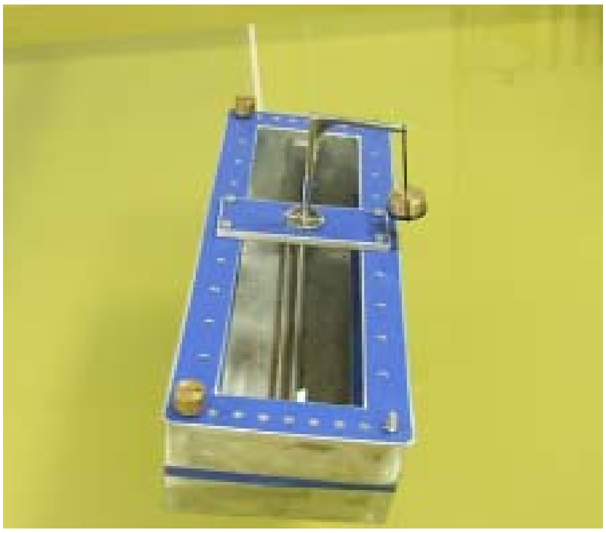

Fig.8. The construction of a rectangular pontoon model.

3.4. Submarine Stability Research Station.

The Polish Navy is equipped with a few submarines. The research on submarine stability is not as frequent as on normal ships but it is very important for our navy. A submarine stability research station is provided with an experimental tank which enables us to initiate research. In the preliminary stage of research it will be possible to present operations of emerging and immersing typical for a submarine only. A very narrow group of scientists bring up a matter of stability of a submarine so making use of new possibilities at the station is a step in a direction of research development as far as reacting of a submarine in different operating states is concerned.

4. PRELIMINARY RESEARCH ON THE POSITION OF A MODEL AFTER ITS DAMAGE

Stability research was started in a prepared laboratory stand bed for a warship type 888. Preliminary research consisted of checking operation of measuring instruments of draught, the angle of heel and the angle of trim. This research required calibrating measuring instruments and choosing the appropriate scale.

The measurement of the angle of heel and the angle of trim on a ship's model was carried out in the initial period of preliminary research when the compartment was damaged. The compartment damage simulation can be done by opening the suitable valve situated in the bottom of the model's bow. The model is trimmed on the bow after flooding the compartment. The measured parameters of values of the model's position were similar to the values of the real object for suitable weight. The difference of measured parameters of values can be affected by the position of the gravity centre of the model and the gravity centre of a real object. The scheme of ship's model with a damaged compartment is shown in the computer window in Figure 9.

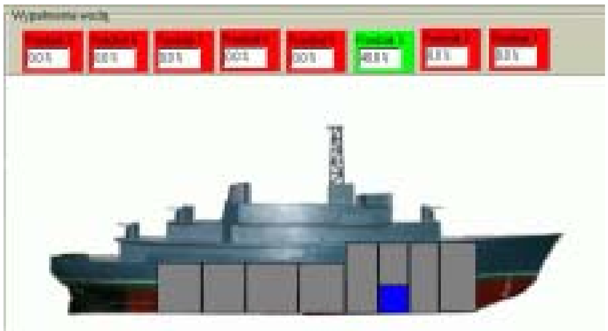

Figure 9. The scheme of ship's model with damaged compartment

During the second part of the preliminary research we tested a stand bed while simulating dynamic influence of flowing air on the warship's model. The stand bed is shown in Figure 10.

Figure 10. The stand bed for ship's dynamic stability simulation.

The initial speed of flowing air was measured directly from the unit of fans. The value of the air speed reached only 3 m\s. Since the level of air speed was too low to cause the dynamic heeling of the model, the stand bed was equipped with a coat. After this operation the air stream was concentrated and the air speed level increased to 6,5 m/s. The value of the air speed was enough to simulate dynamic heels of the model.

5. CONCLUSIONS

The research on stability and unsinkability of ship's models will be the source of knowledge to start researching of real warships.

The presented research station will allow conducting research and exercises including many stability problems, especially damage stability and unsinkability

The main emphasis was laid down on a possibility of creating different events scenario concerning every day ship operation. Students will develop habits and gather experience in the early stage of training. Running the exercises at well prepared station will allow people responsible for sailing safety to increase their qualifications and skills. This is important since the Polish Navy ships take part NATO in international exercises held in military conflict regions.

The simulation of damage states at a suitably prepared research station allows to form the habits of analysis and to produce new assessment or to make decisions to protect against critical situations.

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