PRELIMINARY STUDIES OF EMERGING AND IMMERSING SUBMARINE'S MODEL

Waldemar MIRONIUK

Katedra Eksploatacji Jednostki Pływającej Akademii Marynarki Wojennej
Wydział Nawigacji i Uzbrojenia Okrętowego ul. Śmidowicza 69, 81-103 Gdynia,
tel. (58) 626 27 24, e-mail w.mironiuk@amw.gdynia.pl

Summary

Stability studies, including damage stability and unsinkability of submarines, makes a source of knowledge about the behavior of the ship after the flooding of the compartments. In order to carry out research in the Naval Academy the laboratory test bed has been designed and constructed to allow the position of laboratory immersing and emerging submarine model, enabling simulation the damage of the hull of the submarine model, and thus better recognition of the phenomena occurring in the operation of the ship. Brief characterization of failure of ship and submarine accidents stressing the merits of the subject undertaken have been presented at the article. Description of the test stand for the research over stability and unsinkability of submarines and of possibilities of its usage in training of ship managing crew has been presented in the paper. Presented Preliminary results of experimental tests of immersing and emerging submarine model have been confirmed the assumption built design of the laboratory.

Keywords: damage stability, survivability, submarine, safety on the sea, ships damage

BADANIA WSTĘPNE ZANURZANIA I WYNURZANIA MODELU OKRĘTU PODWODNEGO

Streszczenie

Badania stateczności, w tym stateczności awaryjnej i niezatapialności okrętów podwodnych, stanowią źródło wiedzy na temat zachowania się okrętu po zatopieniu jego przedziałów. W celu przeprowadzenia badań W Akademii Marynarki Wojennej zaprojektowano i zbudowano stanowisko laboratoryjne umożliwiające zanurzanie i wynurzanie modelu okrętu podwodnego, symulowanie przebicia kadłuba modelu okrętu podwodnego i tym samym lepsze poznanie zjawisk występujących w eksploatacji okrętu. W artykule dokonano krótkiej charakterystyki awarii okrętowych i wypadków okrętów podwodnych podkreślając zasadność podjętej tematyki. Przedstawiono opis stanowiska do badań stateczności i niezatapialności okrętów podwodnych oraz możliwości jego wykorzystania w procesie szkolenia kadry kierowniczej okrętu. Zaprezentowano otrzymane wyniki wstępnych badań eksperymentalnych zanurzania i wynurzania modelu okrętu podwodnego, które potwierdziły założenie projektowe zbudowanego stanowiska laboratoryjnego.

Słowa kluczowe: stateczność i niezatapialność, okręt podwodny, bezpieczeństwo pływania, wypadki i awarie okrętowe

INTRODUCTION

More than 220 submarines experienced break-downs during peaceful actions of the XX-th century [1]. Collisions with other sea going ships, mistakes of crew, fires and explosions were the most often reasons of the submarines' disasters.

Unfortunately, superpowers having huge ships, especially nuclear-powered ones, are very often convinced that the ships are indestructible, failure-free and unsinkable. If natural aiming at maximal arming of the ship's space is added to the above, quite often not enough room is left for the safety of crew. Countries of developed economies, holding powerful submarine fleets, do invest in development of underwater rescue systems. Disasters of submarines and related pressure from families of casualties and from the entire world for explanation of causes of deaths of the crew carrying out activities in peace conditions are the main reasons of these investments. Selected break-downs and disasters of submarines in the XX-th century are given in the table 1 below.

Table 1. Selected disasters and failures of submarines after the 2nd world war [1,5]

Country	Date of occurrence	Description of failure/accident
1	2	3
Great Britain	1950	HMS „Truculent" sank after colliding with a trading ship at the Thames Estuary.
USSR	4 July 1961	During patrol operation, failure of nuclear reactor happened on board of K-19 submarine (hotel-class). 7 seamen died in the accident.
USA	10 April 1963	During deep-diving tests performance, „Thresher" submarine did not return on water surface. Failure of sea water system in engine room was a cause of the disaster. All 129 crewmembers died.
USA	22 May 1968	„Scorpion" submarine sank probably due to explosion of her own torpedo. All crew members died.
USSR	7 April 1989	Fire broke out on board of "Komsomolets" submarine, a watercraft of MIKE K-278 class. 41 seamen died in the disaster.
Russia	12 August 2000	OSCAR II class submarine sank during manoeuvres of the Northern Fleet – at the depth of 108 metres. All 118 crew members and probably 12 other officers-observers died.

As a result of collision with another sea going vessel or navigational obstacle, running aground, shelling, explosions of mines etc., a ship may experience damages to hull plating, in the aftermath of what water rushes into her interior. In such a case, surviving depends on:

- keeping the ship's floatation in such a balance state which still allows performance of basic functions, however in very limited extent sometimes,
- keeping a given stability allowing performance of the above-said functions, despite of heeling moments occurrence.

It results from the conducted literature analyses that most damages are caused by technical failures and mistakes made by the ships crews (fig 1).

Therefore, considerable number of the world's naval fleets pays more and more attention to improvement of the ship's damage control elements. Regardless of constructional considerations, conduction of proper training and exercises on the damage control within a scope of a struggle for the vessel's survivability is one of activities increasing operational safety of ships and their crews. Those training are run in respectively adopted centres, equipped with simulators and proper apparatuses. In order to meet expectations of a growing interest in problems regarding evaluation of the ship's stability and unsinkability as well as of the navigational safety improvement, a specialist stand for execution of tests on the damage stability and unsinkability of a submarine's model has been executed.

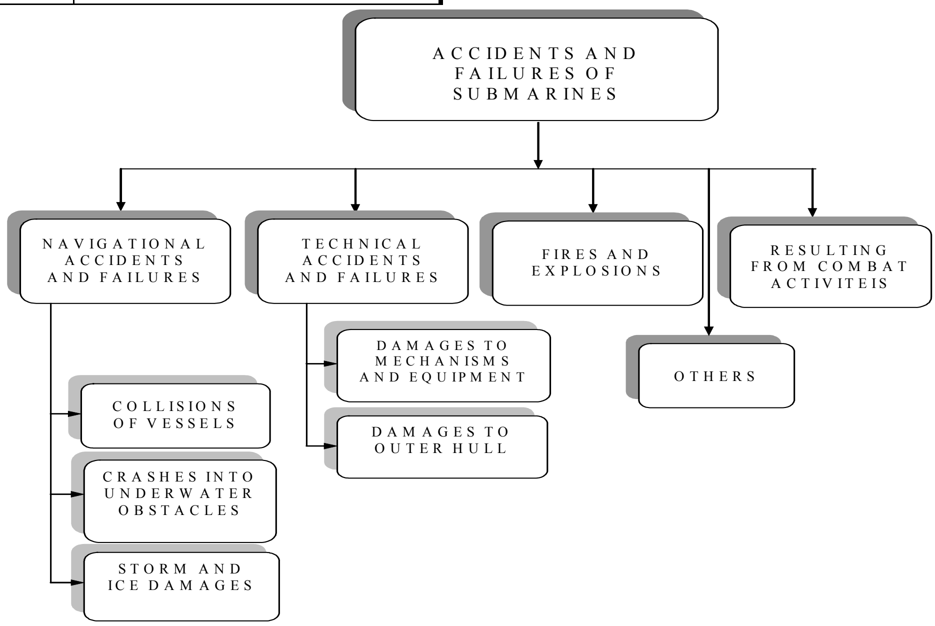


Fig.1. Division of submarines accidents and failures

STAND FOR TESTS ON STABILITY AND UNSINKABILITY OF SUBMARINE'S MODEL

Research on stability and unsinkability of submarines make a source of knowledge about the watercraft's performance after her compartments have been flooded. Possibility to simulate punctures of hulls on models of real objects adopted for this reason is an advantage of that research executed in the laboratory station.

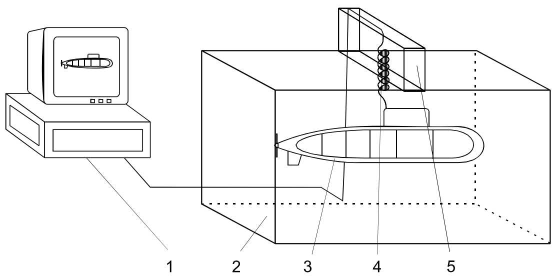
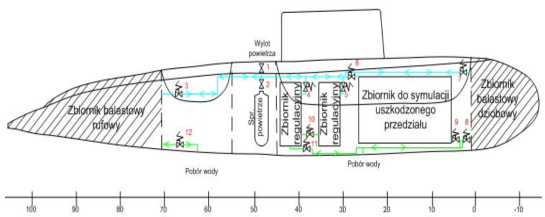


Fig. 2. Scheme of stand for tests on stability and unsinkability of submarine's model:
1- operator's stand, with computer controlling and registering parameters of model's position, 2 – basin of submarine's model, 3 – submarine's model, 4 – feeding cables, 5 – grip of feeding cables

In current stage of the works, the submarine's model, computer controlling the tests and basin are main elements of the stand for research on stability and unsinkability of the watercrafts' models. Hull of the model has been made based on the body lines in appropriate scale. The submarine's model is a basic object of the research and it is equipped with specialist instrumentation for measurements of positions in various operational conditions. Its body is given in figure 3.

Fig. 3. Model of submarine [4]

According to assumptions made in advance, interior of the model has been divided into 5 water-tight compartments. Total volume of all the model's compartments is 55.53 dcm^3. It is equipped with - located in bow and stern compartments - ballast tanks enabling immersing and emerging of the watercraft and with a ballast system for piping water in and from the tanks. Correction of trim and the model's position at assigned depth are shall be executed by means of two regulation tanks and the ballast system. The ballast system is functionally connected with a system of compressed air. Filling and expelling water from the tanks shall be executed with an appropriate sequence of opening and closing BURKERET type electromagnetic valves installed on the submarine's model. The compressed air system with the electromagnetic valves is given in figure 4 and they are marked with a blue colour. Piping water into and from the tanks is also executed via the mutual system marked with a green colour in figure. The system of filling and expelling water from the model's tanks designed in such a way has allowed minimization of a number of applied operating elements. Hence, it has decreased degree of complication of electrical and pneumatic systems and resulted in reduction of the model's weight.
Scheme of location of the ballast and regulation tanks and of a tank allowing simulation of the watercraft compartment's damage is given in figure 4.



Legend:

Zbiornik balastowy rufowy	Stern ballast tank
Wylot powietrza	Air outlet
Spr. powietrze	Compressed air
Zbiornik regulacyjny	Regulation tank
Zbiornik do symulacji uszkodzonego przedziału	Tank for simulation of damaged compartment
Zbiornik balastowy dziobowy	Bow ballast tank

Fig. 4. Scheme of ballast system and location of tanks in model's hull

View of the submarine model's compartment equipped with the regulation tanks and the elements of system for her diving and emerging are given in figure 5.

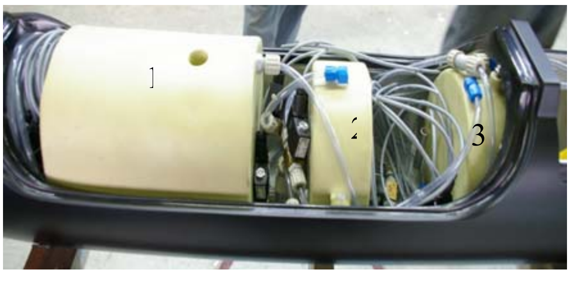


Fig. 5. View of submarine model's compartment: 1 – tank enabling simulation of watercraft compartment's damage, 2, 3 – regulation/trim tanks

The submarine's model has been equipped with the compressed air system that allows blowing the ballast and regulation tanks. Scheme of the submarine model's compressed air system is given in Figure 7. These operations are controlled by a program installed on the computer. The screenshot shown in Figure 6 presents the window of the program.

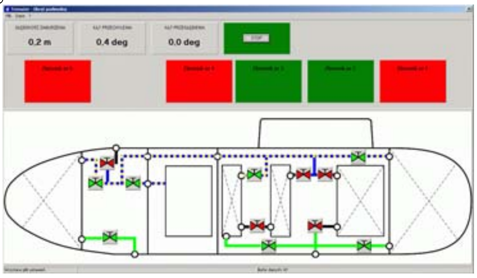
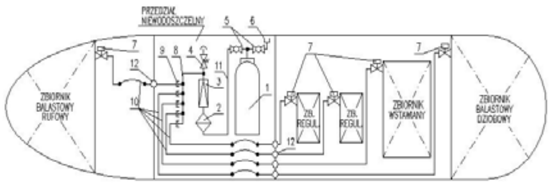


Figure 6. The window of computer program



Legend:

zbiornik balastowy rufowy	Stern ballast tank
przedział niewodoszczelny	Non water-tight compartment
zb. regul.	Regulation tank
zbiornik wstawiany	Insertable tank
zbiornik balastowy dziobowy	Bow ballast tank

Fig. 7. Scheme of submarine model's compressed air system [4]:1 - cylinder with compressed air, 2 – linear filter, 3 – reducing valve, 4 – safety valve, 5 – ball valve, 6 – cylinder charging terminal, 7 – electromagnetic valves, 8, 9 – air distribution station, 10 – low pressure conduits, 11 – high pressure steel conduit, 12 – bulkhead passage for air conduits

An ISA P20 type inclinometer, of ±60° range, has been used to measure angles of heel and trim of the model. This sensor is fed with voltage of 12 V. Principle of the inclinometer operation consists in determining acceleration factor expressed with the following formula:

$$g_n = g * \sin \alpha \qquad (1)$$

where: g_n – acceleration factor
g – gravitational acceleration
α – angular displacement

A weight suspended from a spring inside the sensor moves at the time of deflection. This movement is registered by two capacitor electrodes which generate voltage measured on the sensor's outlet. This voltage is then recalculated onto an angular measure. Values of the angles of heel are displaced on the computer monitor. Measurements of the angles of heel and trim are executed simultaneously in two planes - X-X and Y-Y (fig. 8).

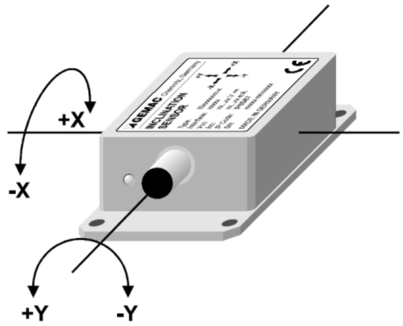


Fig. 8. Picture of inclinometer

Voltage makes an output signal from the inclinometer. The voltage is registered via a measuring card installed in the computer and recalculated onto the angular scale. Signals gathered from the sensors are transmitted by conductors to the computer to be displayed on the monitor in a form of ready parameters of the watercraft's position.

ASPECTS OF LABORATORY STAND'S USING

The said laboratory stand, equipped with the submarine's model, is designed and constructed the way that ensures:

- remote diving and emerging of the watercraft's model by means of filling and blowing the ballast tanks;
- adjustment of the watercraft's position by means of water volume changing in the regulation tanks;
- adjustment of trim by flooding the ballast tanks in the bow and stern of the model;
- possibility of simulating a damage of the watercraft's selected compartment.

Thanks to the appropriate instrumentation, it is possible to make the computer visualisation of the watercraft's position and to register – in real time – such parameters as the following:

- bow draught,
- stern draught,
- angle of heel,
- angle of trim.

Tests on floatation and stability of the submarine's model shall be executed on the stand constructed in such a way – also after compartment of the watercraft has been damaged. The research conducted on the submarine model's stand shall also allow determining time of the model's compartment flooding after the hull has been damaged. This station may be used for improvement of skills and habits when:

- evaluating and reconstructing stability of watercraft, e.g. after her compartment has been flooded;
- elaborating and improving procedures for taking the watercraft off the sea floor;
- determining coordinates of centre of mass and upthrust in emergency states.

Results of the research shall make basic information to be used in aided decision making process for persons fighting with break-downs of submarines, what shall have significant impact on increase of the watercrafts operation security.

PRELIMINARY RESEARCH ON MODEL'S FLOATATION

A leak proof test was executed on the model within a scope of preliminary experimental research. It consisted of three stages out of which each one took 24 hours. In the first stage, the model was placed at the depth of 0.5 metre, then at the depth of 5 metres and again 0.5 metre. Scheme of the watercraft positions during the experimental research is given in picture 9. The leak proof test was completed successfully.

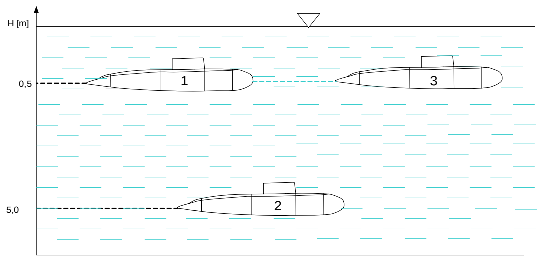


Fig. 9. Scheme of watercraft positions during experimental research

CONCLUSIONS

The presented laboratory stand enables execution of tests and practices covering a number of problems regarding stability, including damage stability and unsinkability of submarines' models.

Conduction of laboratory exercises on a stand prepared in such a way shall allow constant improvement of qualifications and educational level of persons responsible for safe navigation, especially as watercrafts of the Polish Navy more and more take part in warfare in regions of armed conflicts and in NATO international exercises.

Simulation of outer hull damage on stands suitably prepared for tests on watercraft models' responses allows development of habits to analyze and correctly evaluate situations and to make right decisions preventing, for instance, watercraft sinking.

Model, equipped with measurement sensors of angles of heel and trim, and of liquid level in compartments, shall enable determination of its position in a given damage condition. Knowledge about the basic stability parameters shall facilitate making decisions on how to fight with break downs.

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Kmdr dr. inż. **Waldemar MIRONIUK**
Akademia Marynarki Wojennej, Wydział Nawigacji i Uzbrojenia Okrętowego,
ul. Śmidowicza 69
81-103 Gdynia,
tel. (58) 626 27 94,
e-mail
w.mironiuk@amw.pl