**Scientific Journals**
**Maritime University of Szczecin**

**Zeszyty Naukowe**
**Akademia Morska w Szczecinie**

**2013, 35(107) pp. 15–21**
**ISSN 1733-8670**

**2013, 35(107) s. 15–21**

# Innovative software for planning and simulation of cargo handling and ballast water exchange on the ship

**Tomasz Cepowski**

Maritime University of Szczecin
70-500 Szczecin, ul. Wały Chrobrego1–2, e-mail: t.cepowski@am.szczecin.pl

**Key words:** ship, bulk carrier, loading calculator, water ballast, exchange, loading, unloading, software, computer program, simulation, stability, strength, planning

**Abstract**
The paper presents an innovative computer programs "Kalkulator" and "Sekwencja" for planning and simulation of cargo handling operations and the exchange of ballast water for bulk carrier B-517 series. The software is designed to develop and simulate particular loading stages based on the loading programs or water ballast exchange plans. The programs presented in article show new trends in development of loading calculators.

## Introduction

Currently used methods for checking the stability and strength of the ship's hull based primarily on the use of a loading calculator. According to [1] loading calculator is a computer system to calculate and control the loading conditions of compliance with the applicable requirements for stability and strength of the ship. Practically loading calculators are in the form of software installed on a specially designated for that purpose computer. Both the software and the computer must meet the requirements of classification societies such as [2]. These requirements are primarily guaranteed reliability and proper functioning of the calculator loading.

There are following modules in typical loading calculator:

- module to enter the weight of cargo, stores, ballast, icing and allows archiving of these data;
- module that contains the configuration of compartments, the hydrostatics data and the distribution of the ship weight;
- module of hydromechanics calculation;
- module of presentation of the calculation results: values for stability, hull strength, draft, trim and heel of the ship;
- module to draw up the reports;
- draft survey module;
- control segregation of dangerous goods module.

Figures 1–4 present a sample modules of weight and presentations of stability parameters and the strength of the hull in m/v Gdynia loading calculator.

Currently used loading calculators are primarily used to enter data describing the loading condition of vessel and verify the stability and strength criteria in one of two operating states:

- port condition;
- seagoing condition.

Selection of the operational condition depends on whether is controlled the final loading condition state in which the ship is going to sea or particular loading stage of the vessel during cargo handling operations at the port.

On the ship, in addition to loading calculator is available technical documentation that is designed for the proper planning of cargo handling operations. This technical documentation include, among others: "Stability booklet", "Information on longitudinal strength" and "Loading instruction". In particular, "Loading instruction" includes procedures that must be followed in handling the ship and example loading programs depending on the type of load and taking into account the particular loading stages. The procedures presented in the loading instructions are designed primarily for ship safety during handling operations.

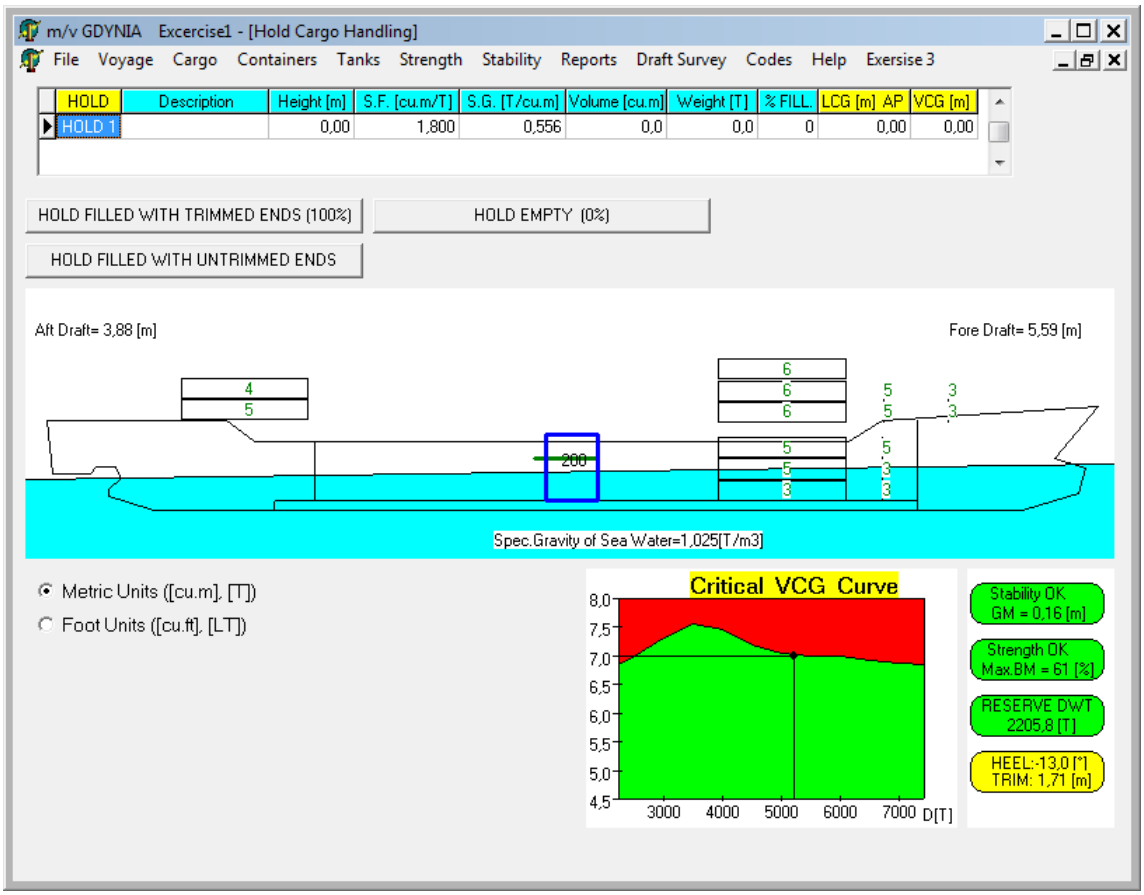



Fig. 1. Modules to enter the weight of cargo and presentation of the stability parameters developed in [3]

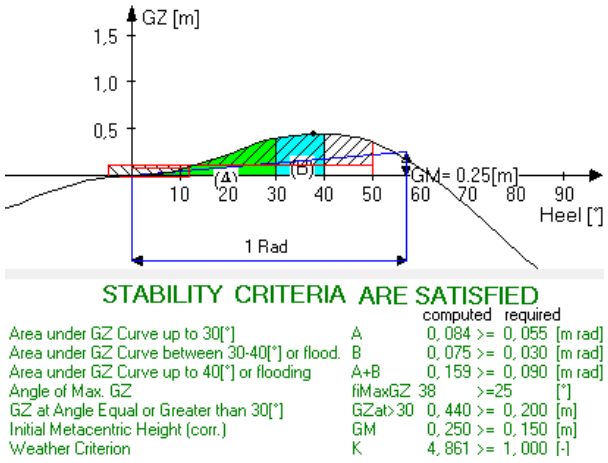



Fig. 2. Righting arm curve and summary of stability criteria developed in [3]

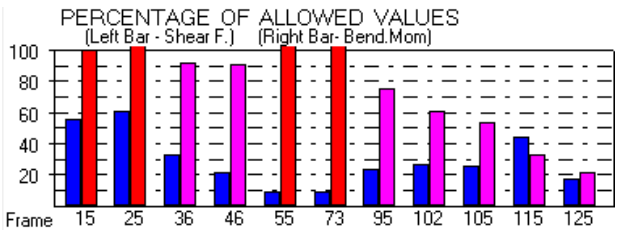



Fig. 4. Percentage of internal forces in relation to the limit values developed in [3]

The following criteria should be considered in these procedures [4]:

- internal forces cannot exceed permissible values;
- ship's draught fore and aft cannot exceed the depth of the harbor;

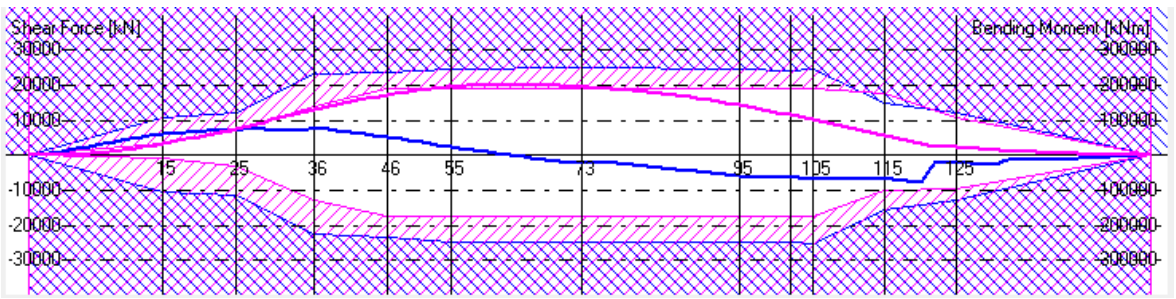



Fig. 3. Distribution of internal forces in relation to the limit values developed in [3]

– ship's stability at particular loading stage must be satisfactory.

## Selected problems

Loading instruction requires verification not only the final loading stage in which the ship is out to sea, but also all particular loading conditions in the port during cargo handling operations.

Every particular loading stage consists of the following elements:

– weight of cargo in specified compartment;
– weight of ballast in specified water ballast tank;
– weight of stores.

The problem is that the existing loading calculators don't have the option to load the entire loading plan which consists of a set of particular loading states at the port and at the final loading state.

Therefore, it isn't possible to quickly check the entire loading plan of the vessel in accordance with specified requirements.

Currently used calculators are allowed to manual data entry for the particular load state. Therefore, control of loading discharging plan requires an iterative implementation of all particular stages of loading. But accurate control of all particular loading stages is laborious and time consuming.

A similar problem occurs in the planning of ballast water exchange at sea. Ballast water exchange involves the checking of the many particular loading stage at sea. The number of particular loading states depends on the number of ballast tanks.

Using of existing loading calculators to plan of ballast water exchange is difficult, time consuming and requires additional manual calculations.

Therefore, the practical purpose of the study was to develop software that allows for more efficient planning of cargo handling operations and the exchange of ballast water.

Therefore, the paper proposes the following new developments:

– automatic design, verification and simulation of all particular loading states during handling at the port;
– automatic design, verification and simulation of all particular loading states during ballast water exchange at sea.

## The computer programs "Kalkulator" and "Sekwencja"

The practical aim of the research was to develop the following software:

– the computer program "Kalulator" used to the control of stability and strength, and to simulate the handling of the ship or ballast water exchange;
– the computer program "Sekwencja" used to develop all particular loading stages based on the plan of loading / unloading and ballast water exchange plan.

This software was developed for bulk carrier series B-517 with the following dimensions:

– length overall $L_c$ = 198.4 m;
– length between perpendiculars $L_{pp}$ = 185 m;
– breadth $B$ = 24.4 m;
– draught moulded $d$ = 11 m.

General plan of holds and tanks bulk carrier B-517 series is shown in figure 5.

The programs "Kalkulator" and "Sekwencja" were developed using Borland Delphi 3.0.

There are following modules in the computer program "Kalkulator":

– module to enter cargo weight (Fig. 6);
– module to enter ballast weight (Fig. 7);
– module to enter stores weight (Fig. 8);
– module to present weight specification (Fig. 9);
– visualization modules for deployment of cargo, ballast and draft, trim and heel (Fig. 10);
– modules for visualizing the results of stability calculations (Fig. 11);
– modules for visualization of the longitudinal strength calculations (Fig. 12).

The computer program "Sekwencja" consists of an interface allowing the creation, saving and loading cargo plan taking into account the weight distribution of the load, ballast masses and stores (Fig. 13). This program develops all particular loading stages based on the plan of loading / unloading and ballast water exchange plan.

The procedure for use of the programs "Kalkulator" and "Sekwencja" to develop a plan for handling the ship or to plan for ballast water exchange consists of the following steps:

– manual development of an initial loading condition using the "Calculator" program;
– manual development of a plan of loading / unloading and ballast water exchange using the "Sequence" program;
– automatic calculation of all the particular loading stages using the "Sequence";
– run the simulation of loading or ballast exchange in the "Calculator" program.

The website [5] presents the simulation of heavy cargo loading developed using programs "Kalkulator" and "Sekwencja".

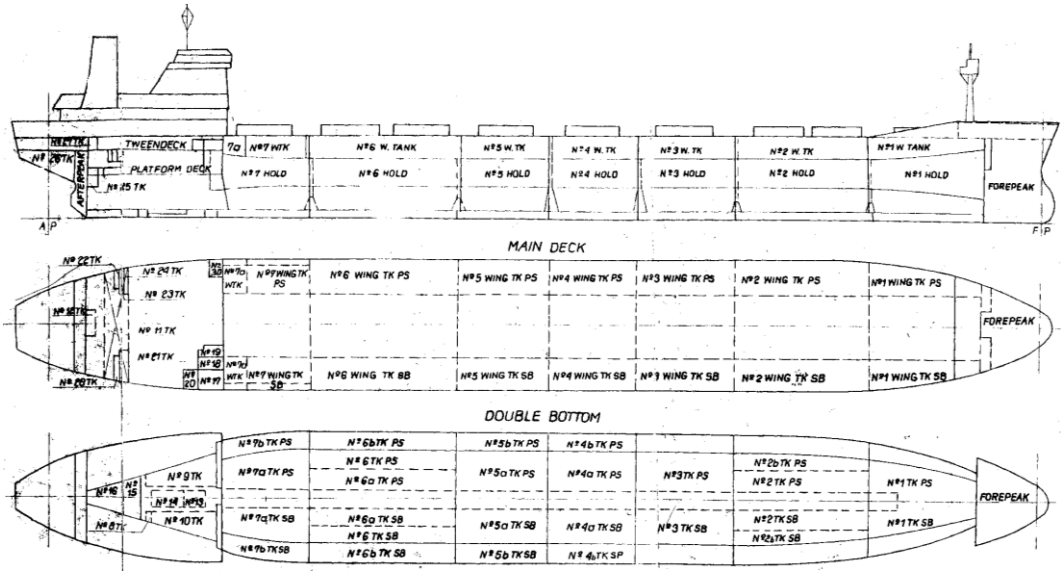



Fig. 5. General plan of holds and tanks bulk carrier B-517

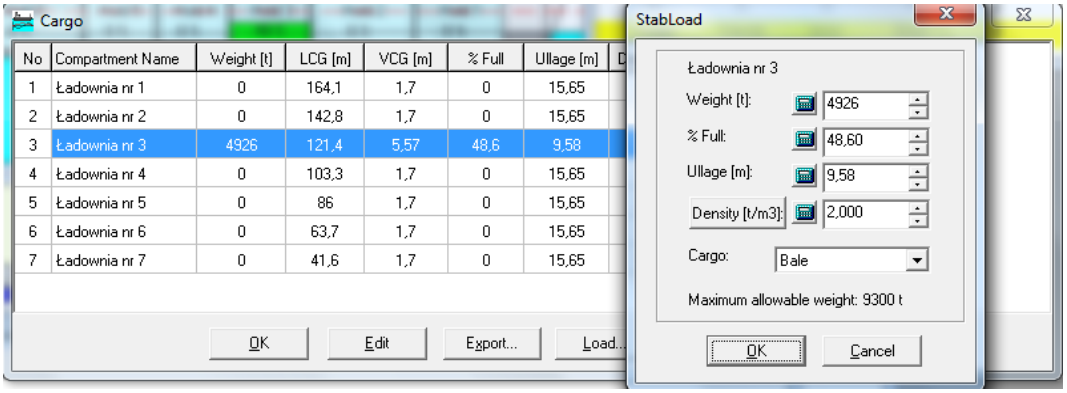



Fig. 6. Module to enter cargo weight in the computer program “Kalkulator”

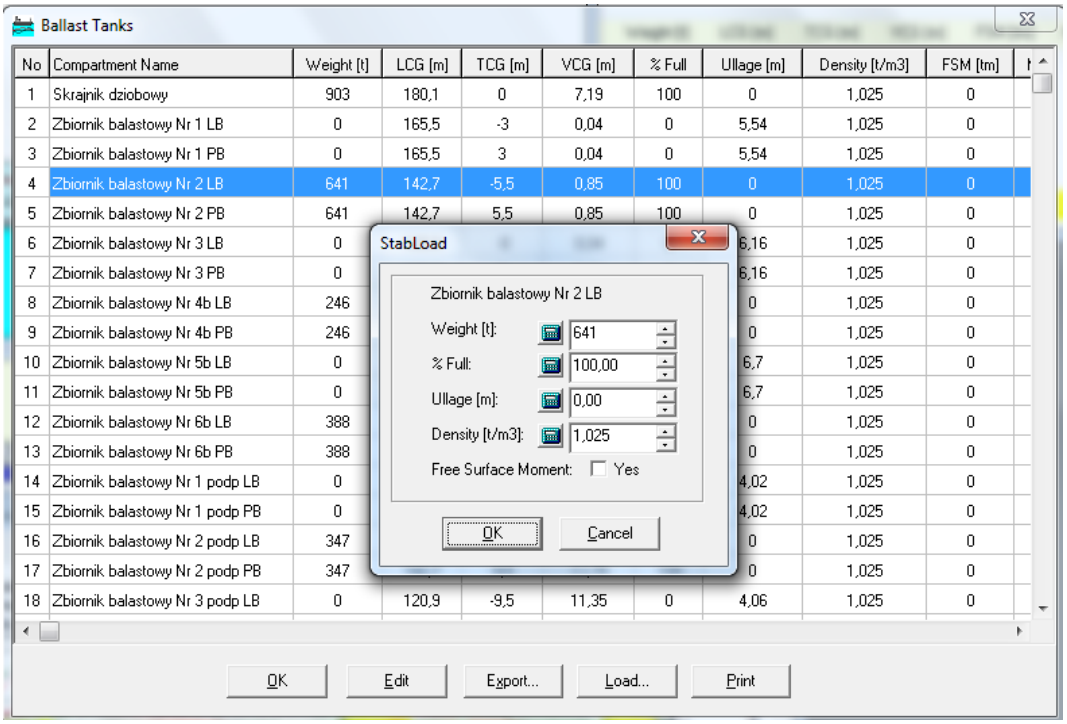
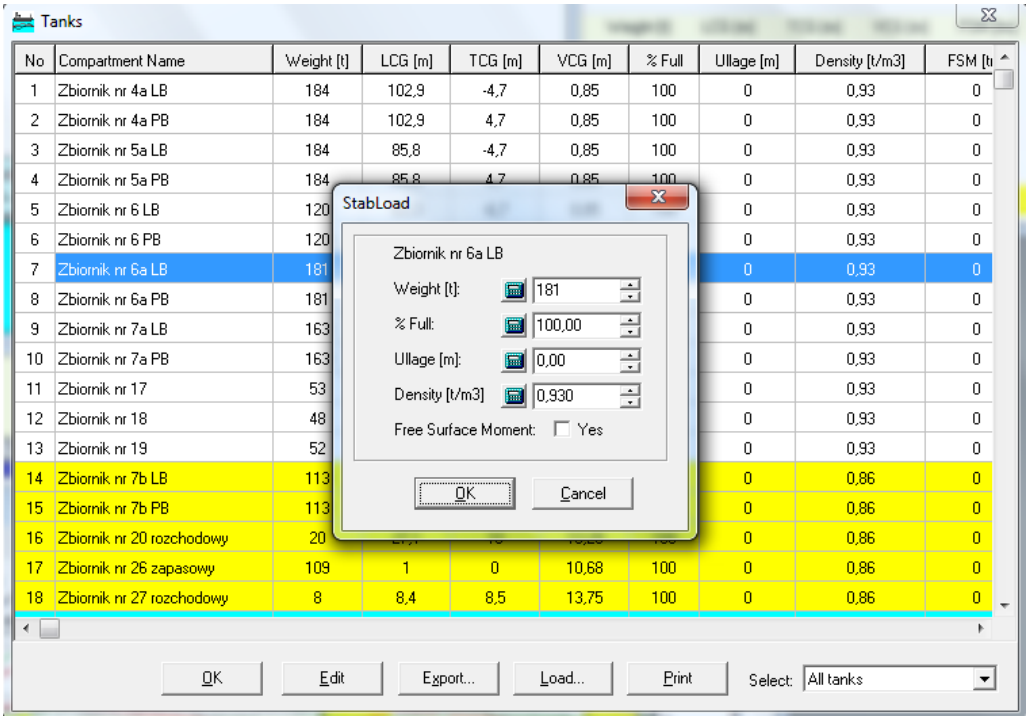
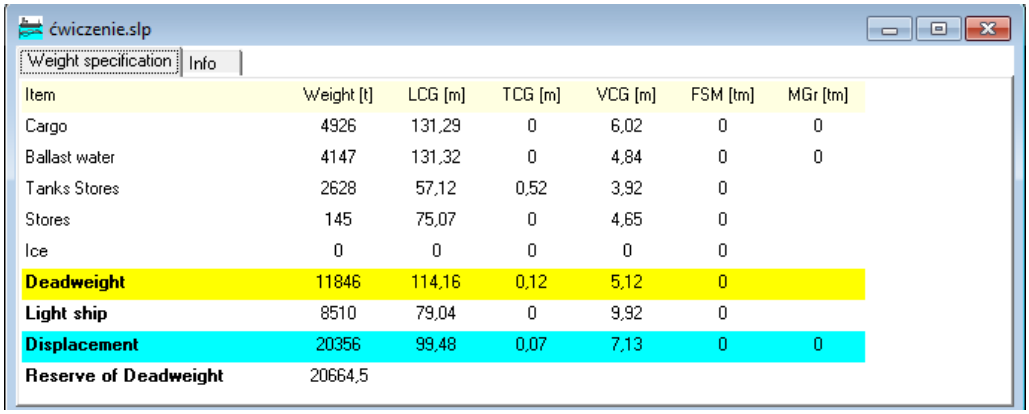



Fig. 7. Module to enter ballast weight in the computer program “Kalkulator”




| No | Compartment Name | Weight [t] | LCG [m] | TCG [m] | VCG [m] | % Full | Ullage [m] | Density [t/m3] | FSM [t |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Zbiornik nr 4a LB | 184 | 102,9 | -4,7 | 0,85 | 100 | 0 | 0,93 | 0 |
| 2 | Zbiornik nr 4a PB | 184 | 102,9 | 4,7 | 0,85 | 100 | 0 | 0,93 | 0 |
| 3 | Zbiornik nr 5a LB | 184 | 85,8 | -4,7 | 0,85 | 100 | 0 | 0,93 | 0 |
| 4 | Zbiornik nr 5a PB | 184 | 85,8 | 4,7 | 0,85 | 100 | 0 | 0,93 | 0 |
| 5 | Zbiornik nr 6 LB | 120 | | | | | 0 | 0,93 | 0 |
| 6 | Zbiornik nr 6 PB | 120 | | | | | 0 | 0,93 | 0 |
| 7 | Zbiornik nr 6a LB | 181 | | | | | 0 | 0,93 | 0 |
| 8 | Zbiornik nr 6a PB | 181 | | | | | 0 | 0,93 | 0 |
| 9 | Zbiornik nr 7a LB | 163 | | | | | 0 | 0,93 | 0 |
| 10 | Zbiornik nr 7a PB | 163 | | | | | 0 | 0,93 | 0 |
| 11 | Zbiornik nr 17 | 53 | | | | | 0 | 0,93 | 0 |
| 12 | Zbiornik nr 18 | 48 | | | | | 0 | 0,93 | 0 |
| 13 | Zbiornik nr 19 | 52 | | | | | 0 | 0,93 | 0 |
| 14 | Zbiornik nr 7b LB | 113 | | | | | 0 | 0,86 | 0 |
| 15 | Zbiornik nr 7b PB | 113 | | | | | 0 | 0,86 | 0 |
| 16 | Zbiornik nr 20 rozchodowy | 20 | | | | | 0 | 0,86 | 0 |
| 17 | Zbiornik nr 26 zapasowy | 109 | 1 | 0 | 10,68 | 100 | 0 | 0,86 | 0 |
| 18 | Zbiornik nr 27 rozchodowy | 8 | 8,4 | 8,5 | 13,75 | 100 | 0 | 0,86 | 0 |

Fig. 8. Module to enter stores weight in the computer program "Kalkulator"




| Item | Weight [t] | LCG [m] | TCG [m] | VCG [m] | FSM [tm] | MGr [tm] |
|---|---|---|---|---|---|---|
| Cargo | 4926 | 131,29 | 0 | 6,02 | 0 | 0 |
| Ballast water | 4147 | 131,32 | 0 | 4,84 | 0 | 0 |
| Tanks Stores | 2628 | 57,12 | 0,52 | 3,92 | 0 | |
| Stores | 145 | 75,07 | 0 | 4,65 | 0 | |
| Ice | 0 | 0 | 0 | 0 | 0 | |
| **Deadweight** | 11846 | 114,16 | 0,12 | 5,12 | 0 | |
| **Light ship** | 8510 | 79,04 | 0 | 9,92 | 0 | |
| **Displacement** | 20356 | 99,48 | 0,07 | 7,13 | 0 | 0 |
| **Reserve of Deadweight** | 20664,5 | | | | | |

Fig. 9. Module to present weight specification in the computer program "Kalkulator"

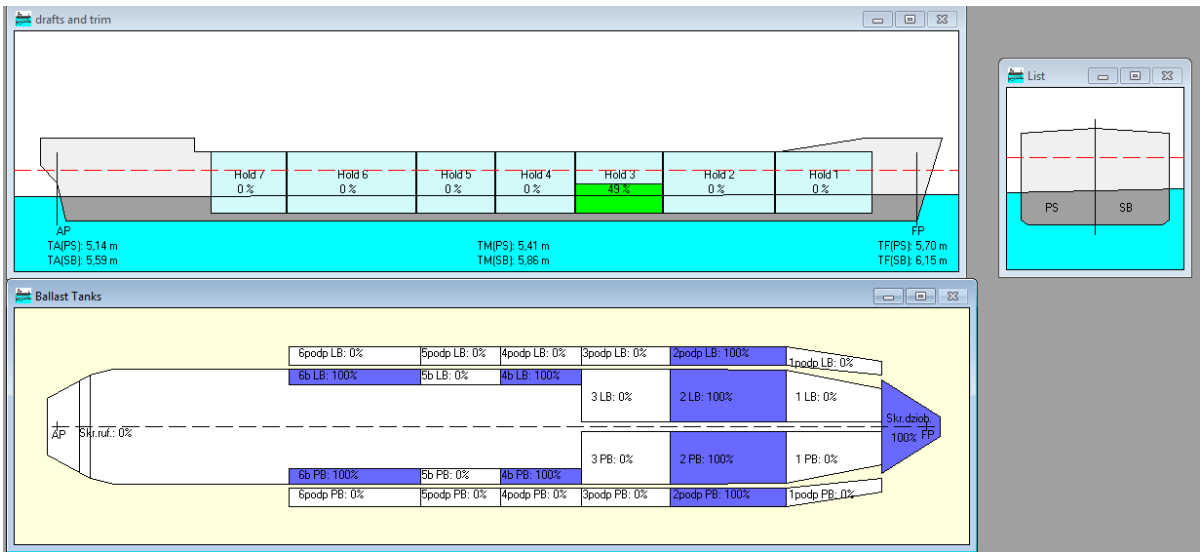



Fig. 10. Visualization modules for deployment of cargo, ballast and draft, trim and heel in the computer program "Kalkulator"

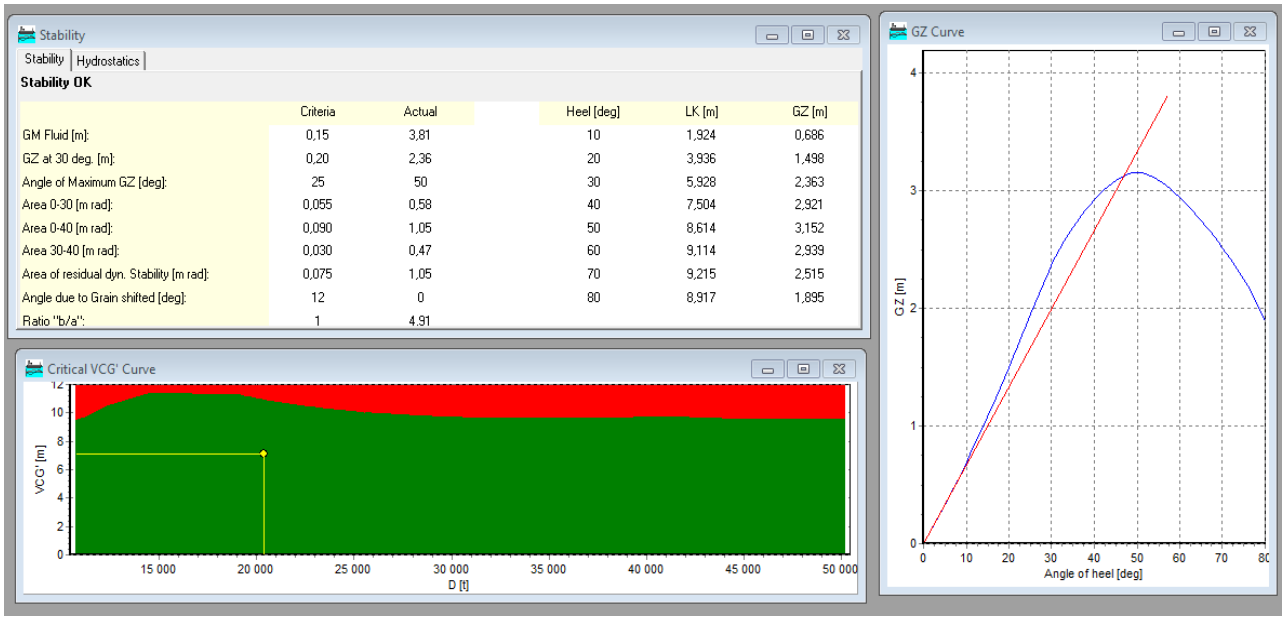



Fig. 11. Modules for visualizing the results of stability calculations in the computer program "Kalkulator"

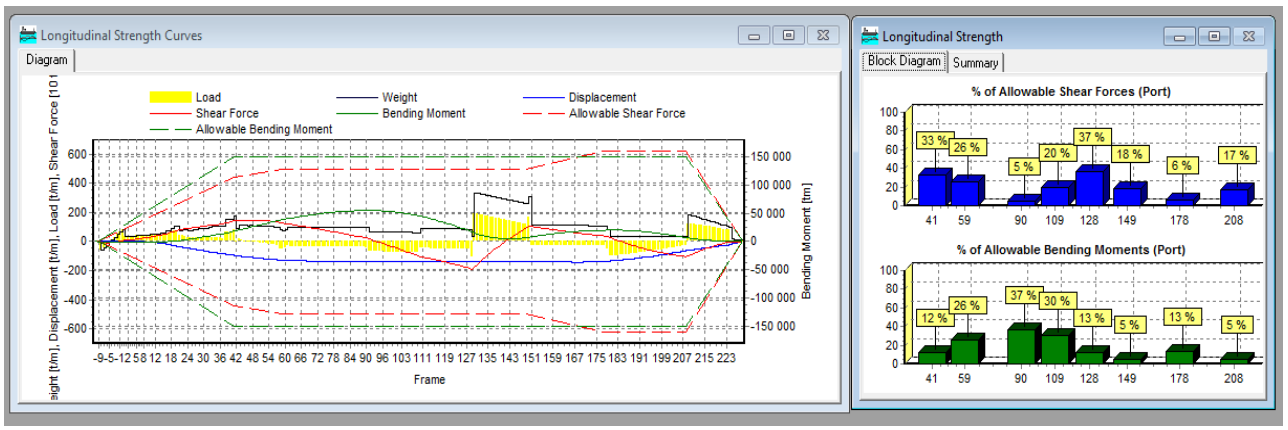



Fig. 12. Modules for visualization of the longitudinal strength calculations in the computer program "Kalkulator"

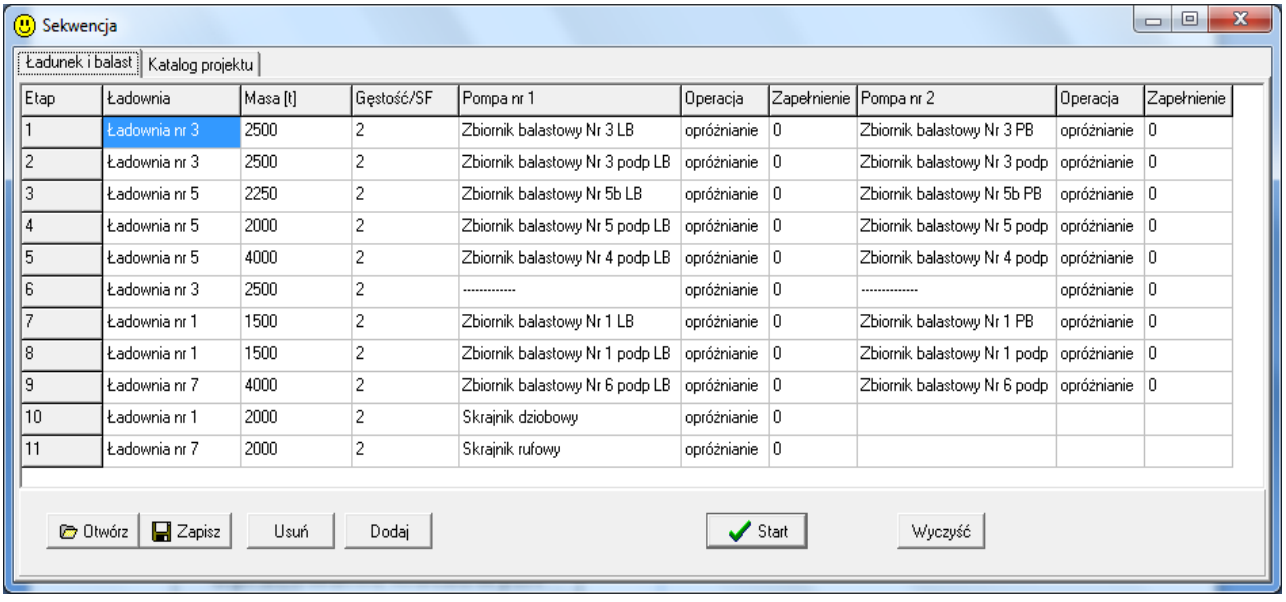



Fig. 13. Computer program "Sekwencja"

## Conclusions

The paper presents a new solution that would allow to:

- the automatic design, verification and simulation of all particular loading stages during handling at the port;
- the automatic design, verification and simulation of all particular loading stages during ballast water exchange at sea.

The proposed new solutions can greatly facilitate and reduce the time for the handling operations planning and ballast water exchange.

Implementation of the proposed solutions in loading calculators may significantly expand capabilities and may to some extent improve the safety of the ship.

The computer programs "Kalkulator" and "Sekwencja" presented in article show new trends in development of loading calculators.

## References

1. DNV: Approval and certification of the software of loading computer systems, Classification Notes No.21.1, 2009.
2. PRS: Zasady uznawania programów komputerowych, publikacja nr 14/P, 2008.
3. Loading Calculator LCCAD ver. 3.0, program for m/v Gdynia prepared by BARTEX Software for Marine Technology.
4. Technical documentation of bulk carrier B-517.
5. Website www.youtube.com/watch?v=6rxWr7NMW4A.