Stability of the Ship Using Intact Stability Criteria and Empirical Formulas

ALEXANDRU-STEFAN BACIOIU
IONELA GOIA
Transport Faculty
University Politehnica of Bucharest
ROMANIA

Abstract: Regarding ship stability and stability elements various problems should be addressed, however this paper talks about some of the important, however often given less importance. It is a must onboard a ship to recognize the stability problems which are not always present but they can be an issue which should be addressed. Regarding ship stability issues there are various software which analyse and give an assessment which is checked by the end user. A study on ship hull, stability and stability elements is presented in the paper.

*Key-Words:*autoship, stability, ship, shipping, intact stability criteria, imo
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1 Introduction

Stability of the ship is in a direct link with the logistical matters and the pressure on the construction and stability elements due to increasing demand of the goods carried. The cost of transporting goods to centres of demand from warehouses and logistical area need to be minimized because this forms a part which is essential regarding profitability for logistics companies. [2] The transportation problem is a type of linear programming problem made to minimize the cost of distribution for products from shippers to receivers. The most common practical application is of moving a product from point A to point B or from several points to several points depending on the complexity of the factors involved. There are also some constraints which must be satisfied like: the number of transported goods must be equal or match the demand for the locations, the number of goods transported must be less of equal to the total supply, the number of units to be transported must be greater or equal to zero, therefore no negative values are accepted. There is also the case of balanced transportation problem, where the supply is equal to the demand. This can be seen as a tool for allocating resources in an optimal way, basically to optimize the transfer of goods between ships and port.

2 Problem Formulation

It is important onboard a ship to recognize the stability problems which are not always present but they can be an issue which should be addressed.
Regarding ship stability issues there are various software which analyse and give an assessment which is checked by the end user. Programs like Autoship, Autohydro or Autopower are used for surface modelling, hydrostatics and stability prediction, resistence and power prediction. Some of the functions are intact stability calculation and reporting, advanced reporting options for hydrostatics, hull lines, damage stability, advanced loading condition, floodable calculations, probabilistic and deterministic calculations. Therefore a good analysis of the ship stability regarding cargo loading or unloading is to be considered.[5]

3 Problem Solution

In the figures 1, 2 and 3 can be seen a ship structure for stability using Autoship. This structure is for a medium range ship, however can be scaled for a bigger or smaller ship.

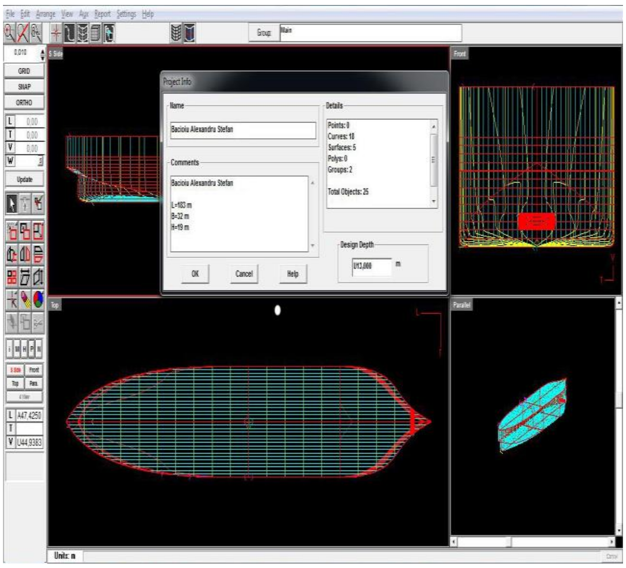

Fig. 1 Info about the project in Autoship

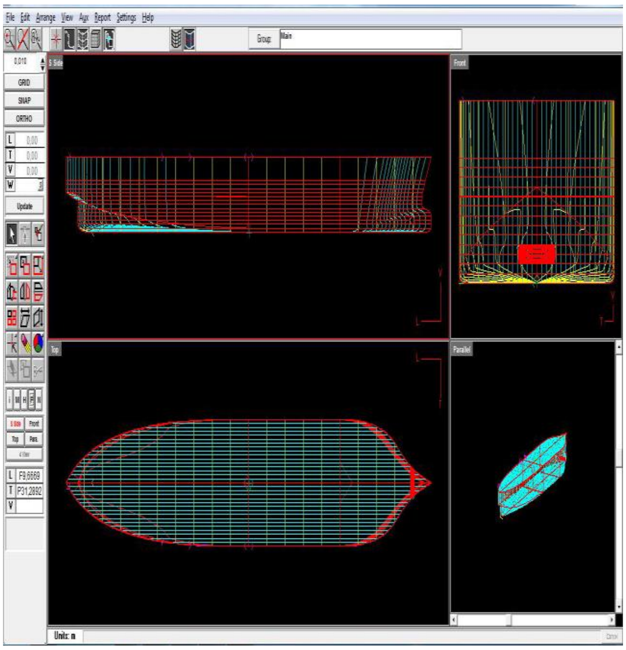

Fig. 2 Ship view in Autoship

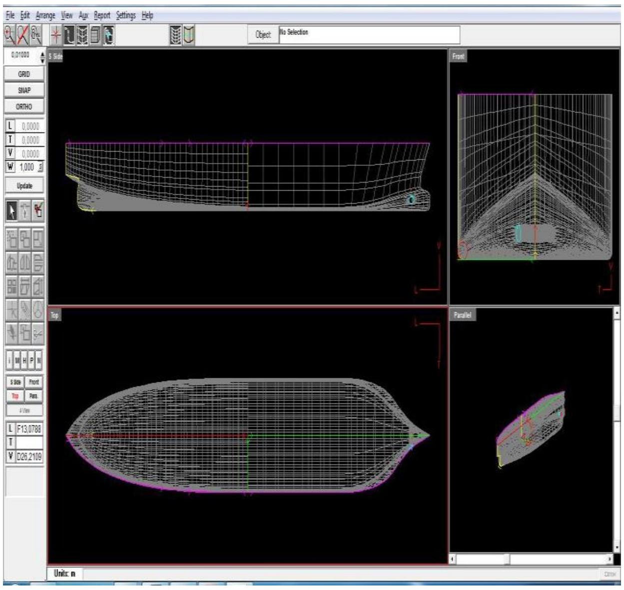

Fig. 3 Ship view in Autoship

Floating surface area calculation
The formula used to perform the calculation is:

$$A_{wi} = \lambda[y_{i0} + 2y_{i1} + 2y_{i2} + \ldots + 2y_{i19} + y_{i20}] \ [m^2] \ (1)$$

$y_{i,j}$ - the half-widths measured at the buttock i and the waterline j

λ - distance between 2 buttocks: $\lambda = \frac{L}{20}$

Calculation of the abscissa of the geometric center of the floating surface
The formula used to perform the calculation is:

$$X_{Fi} = \frac{2\lambda^2}{A_{wi}}\left[10(y_{i20} - y_{i0}) + 9(y_{i19} - y_{i1}) + \ldots + 1(y_{i11} - y_{i9}) - \frac{10}{2}(y_{i20} - y_{i0})\right] [m] \ (2)$$

Hull volume calculation

The formula used to perform the calculation is:

$$V_i = \frac{t}{2}[0 + (A_{w0} + A_{w1}) + (A_{w1} + A_{w2}) + (A_{w2} + A_{w3}) + \ldots + (A_{w7} + A_{w8})] \ [m^3] \ (3)$$

t = draft / number of waterlines

Calculation of ship displacement
The formula used to perform the calculation is:
$\Delta = \rho V$, where ρ is the density of water and V is the volume of the hull

Calculation of the height of the geometric center of the hull.
The formula used to perform the calculation is:

$$K_{Bi} = \frac{t^2}{2V_i}[0 + (0A_{w0} + 1A_{w1}) + (1A_{w1} + 2A_{w2}) + \ldots + (7A_{w7} + 8A_{w8})] \ [m] \ (4)$$

There are systems of a larger complexity that appear frequently appear in the present times in science, technology and real life situations and many different and constantly changing factors are usually involved. As a result the data obtained from their operation mechanisms cannot be easily determined precisely and in practice estimates of them are used. As this is the case with above formulas. [7]
There is also the need to talk about artificial intelligence which can help in identify stability problems. Artificial intelligence is technology relatively new with high potential to modify the world as we know it. It finds applications in many fields of human activity, including services, industry, education, social networks, transportation, among others. The objective is to change the way the artificial intelligence is trained and to add specific conditions which are mostly rare, therefore to develop a better ability to forecast any dangerous situation.

There are specific IMO criteria for the stability of the ships where is mentioned the minimum GM to be maintained in order to maintain an intact stability of the ship and can be found in the Intact Stability Code which have the purpose of recommend stability criteria and other measures for ensuring the safe operation of all ships to minimize the risk to such ships, to the personnel on board and the environment. Initial GM or metacentric height should not be less than 0.15 m. In simple terms, to increase the stability of a ship the containers which are heavier should be placed at a lower position in order to increase the GM.[3]

Height of center of gravity
The formula used to perform the calculation is:

$$\overline{KG} = \frac{KG_{es}\Delta_{es} + \sum_{i=1}^{n} m_i z_i}{\Delta_{es} + \sum_{i=1}^{n} m_i} \quad (5)$$

Table 1 Calculation of center of gravity

Quantities	Notation	Value	S.I. Unit
Empty ship hull center elevation	KG_{es}	Empty ship hull center elevation (value)	m
Elevation of cargoes	z_i	z_i	m
Displacement of empty ship	Δ_{es}	Displacement of empty ship (value)	t
Weight of cargoes onboard	m_i	m_i	t

Using table 1 and formula (5) the center of gravity can be calculated depending on the cargoes onboard, their elevation and weight.
In engineering, the foundation is a special element of a building. In each construction a special group of elements is designed and constructed, which is used for the safe transfer of superstructure loads. [6]
Analyzing the data of vessels that behaved well, and especially the data of vessels that did not survive adverse conditions, various researchers and regulatory authorities defined criteria for deciding if the stability of a vessel is satisfactory. Therefore, it is important to understand that the existing stability regulations are codes of practice that provide reasonable safety margins without giving 100% guaranty that the vessel which meets the requirements can survive all challenges.[4]
According to the International Code on Intact stability, 2008, the following criteria are mandatory for passenger and cargo ships constructed on or after 1st January 2010:[3]
1. The area under the righting lever curve (GZ curve) should not be less than 0.055 metre-radians up to 30° angle of heel.
2. The area under the righting lever curve (GZ curve) should not be less than 0.09 metreradians up to 40° angle of heel or the angle of downflooding if this is less than 40°.
3. The area under the righting curve between the angles of heel of 30° and 40° or between 30° and the angle of downflooding if this angle is less than 40°, should not be less than 0.03 metre-radians.
4. The righting lever GZ should be minimum 0.20 m at an angle of heel equal to or greater than 30°.
5. The maximum righting arm should occur at an angle of heel preferably exceeding 30° but not less than 25°.
6. The initial metacentric height GMo should not be less than 0.15 m.
7. Severe wind and rolling criterion (weather criterion)
In addition to the criteria described above, ships covered by the 2008 IS Code should meet a weather criterion that considers the effect of strong beam wind and waves applied when the vessel is in dead ship condition.

4 Conclusion

International maritime transport has grown both in terms of supply and demand. Future research can be expanded to the subject and to develop further methods of increasing ship stability or to correct it when is necessary. Stability of the ship is in direct link to the stowage plan, cargoes carried onboard, ballast water and other weights onboard. A more detailed paper can be developed starting from this point regarding this matter. More to be done exists, although this matter is also a practical one and additional constraints are to be taken into account. There is the need to discuss about ships used for deep sea shipping and ships used for short sea shipping, however this can be a problem of a higher complexity and can be developed in future papers. There is also the need to discuss the future of shipping regarding stability nowadays. The pressure on the shipping industry is constantly increasing, therefore also this matter is at utmost importance.

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