Bulletin of the *Transilvania* University of Braşov • Vol. 2 (51) - 2009
Series I: Engineering Sciences

CONSIDERATIONS ON THE MARITIME VESSELS BALLAST OPERATION

I. POPA [1] A. POPA[1] E. MACARIE [2]

Abstract: *This paper considers the efficiency of the ballasting operation in order to achieve the navigational safety parameters. With this problem in mind, is carried an analysis of the optimum timing of the ballasting operation, concerning both functional reasons and the amount of water used in order to acquire the desired trim and convenient cruise speed.*

Key words: *criteria, ballast, optimization .*

1. Introduction

The maritime transport achieved in last decade an important development, according to the development of the industry and with the increasing internal and abroad goods traffic as a demand of basic materials, necessary for growing industry needs: ore, coal and oil.

The major development of the specialized transport, which generates an one way movement of the goods (tankers, ore carriers, bulk – carriers, ferry), imposed the design development for the ballast system, in order to achieve a safer navigation when the ship is fully charged as well when the ship is empty. The main goal is to maintain a proper trim and stability and to realize necessary depth for the propeller and to eliminate, in this manner, the cavitations effect.

The main purpose of the ballast system`s efficiency analysis is to obtain new safety criteria for the ballast system and it`s subsystems and secondary some economic criteria, mainly regarding the efficiency of the energy conversion in the ship`s power systems.

2. The Statement of the Optimization Criteria

The optimization of the ballast system will be carried according to the ship mission, choosing one of the following topics analyzed in this paper:

- maintaining the required ballast timing, using pumps whose power and flow rates can realize the conditions required by the operating safety coefficients, considering the improvements in cargo handling operations (charge / discharge operations) [5];
- maintaining necessary draft and trim values in order to realize a decreasing drag force corresponding to the economic speed realized with the new cargo situation;
- the convenient distribution of the ballast onboard in order to maintain acceptable values for bending moments and shear forces and elastic displacements.

3. The Optimum Ballast Timing

The optimum ballast timing is assured for maritime vessels as follows: for liner

[1] Dept. of Naval Installations and Machinery, “Mircea cel Batran” Naval Academy of Constanta.
[2] The Administration of the Navigable Routes

vessels, depending on the safety operation standards; for the bulk carriers, by the reason of limited berthing time and for military vessels referring to the most convenient trim, because there aren`t significant draught value differences [4].

Concerning the Ro – Ro vessels, ferries, barge carriers and container ships, the most common types of vessels used in modern transport activities, there is necessary the existence of appropriate ballast systems in order to counteract rapidly the major draught differences occurred because the unloading operations, respectively as sequel of loading heavy and concentrated cargo, represented by containers and rolling stock.

In the situation of tanker vessels (oil tankers, LNG tankers and LPG tankers), the capacity of the ballast pumps is determined by the reason that the ballasting operation of the bigger ballast tank must be achieved in 8 to 10 hours, and for the bulk carriers, the ballasting operation of the bigger tank must be achieved in 2 to 4 hours.

4. The Decreasing of the Drag Force Value

For a specified vessel, described with the block coefficient C_B, there is a specified value for the Froude number Fr, and when it is exceeded, the drag force will increase significant and speed value will be considered as a critical value; this situation must be avoided (see figure 1). In order to mark out the critical speed value area, and further to highlight and define the hydrodynamic barrier are for various hull types, there is defined an nondimensional value for drag force variation $RL/\Delta\cdot v^2$, as a relation depending on the Froude criteria value [1].

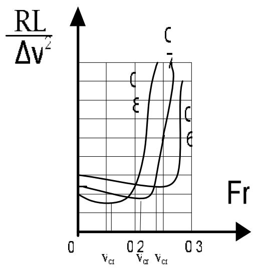

Fig. 1. *Critical speed value achieving*

It is obvious that the unloaded vessel hasn`t the initial fully load designed hull and it is necessary to obtain, concerning the economic operational efficiency (reduced fuel consumption), the critical speed for obtaining the navigational safety for unloaded ship (navigation in ballast condition). This value is determined using the Alexander`s formula (see equation no 1), in knots, where L_{PP} represents the length between the perpendiculars [1]:

$$v_{cr} = 3{,}6 \cdot (1{,}05 - C_B)\sqrt{L_{PP}} \quad \text{[Kn]} \qquad (1)$$

The vessels hull, hydro dynamical modeled through the static characteristic will have the following form (2):

$$R = f(v) \qquad (2)$$

Concerning the dynamic sea state, the vessel`s linear trajectory movement modeling will be carried using the following equation (3):

$$M\frac{dv}{dt} = T(v) - R(v) \qquad (3)$$

where T and R represents the static characteristics for the propeller and hull, determined by mathematic methods.

5. The Optimum Distribution of Ballast Onboard

Even the ballasting rules are strictly respected, for safety reasons, concerning the navigation, the trim, ship stability and the right depth for the propeller; it needs to study the tensiles and the deformations for different ballast situations, with the purpose of hull protection in rough sea.

So, for all the ships, especially tankers, having the length bigger then 180 meters we have to make an analysis of the extreme ballasting cases, having the ship on the typical design situations: ship on wave situation and ship between wave situation, having ballast on the forend and aftend or in amidships tanks.

During the rough sea operations, the wave action modifies seriously the pressure distribution on the wet surface of hull (in this case, the hydrostatic pressures, characteristic for the calm water, are combined with the hydrodynamic pressure).

This variation acts directly on the mass repartition diagrams and over the shear stress, on the length of the ship, assumed to be a rigid girdle put on an elastic environment (bending moment on waves are much greater than the bending moments on calm sea) [2]. The ship on the sea situation is assumed to be possible when the speed vector of the ship have the same magnitude and direction with the speed vector of the wave (figure 2).

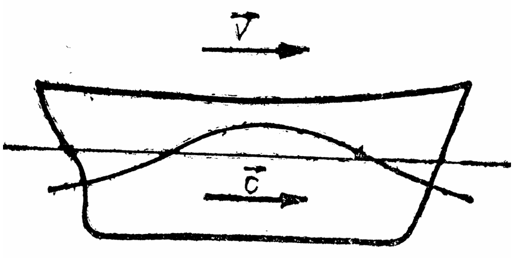

Fig. 2. *Ship on the wave situation*

So, considering the mass diagrams for the calm water we can determine the worst position for a given hull.

Such situation will lead in most cases to maximum stress at amidships and so at the maximum ballast quantities we can take onboard at the ship ends considering maximum tensile the structure can support. In figure 3 there are presented 2 cases for mass distribution diagrams for a ship. So when the loads (in our case the ballast) are distributed preferentially in amidships, the worst situation is the ship between wave situation, and for a mass distribution preferentially at the end of the ship, the worst case is ship on wave situation witch can become critical [3].

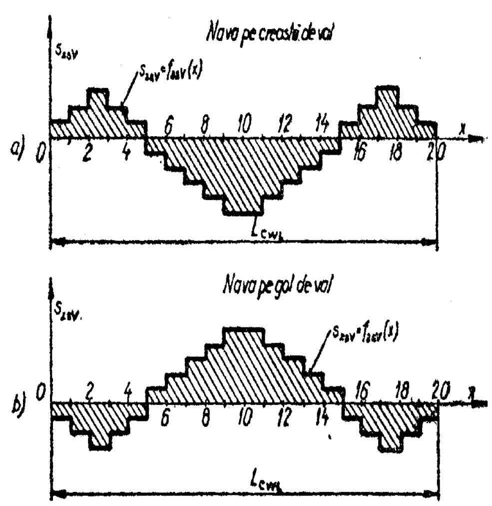

Fig. 3. *The usually cases for mass distribution onboard ship*

When we are studying the static position of the on wave, we can use the model of wave. (figure 5) witch minimize the approximate errors between the modeled wave and the real wave, having a length $\tilde{\lambda} = 1,1 L_{CWL}$, where L_{CWL} is length of the intersection between hull and water, and a standard height $\tilde{h} = 0,64\sqrt{\tilde{\lambda}} - 1[m]$; if the ship have a length less than 120 m, or $\tilde{h} = 6[m]$, for a ship with the length equal or greater than 120 m.

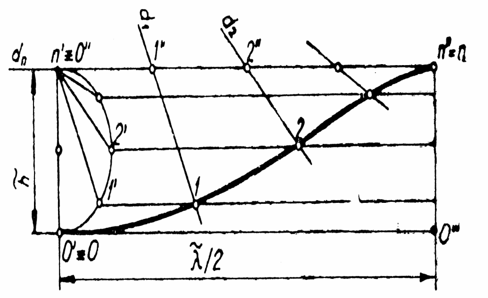

Fig. 4. *The modeling of the wave*

If we are considering the liquid free surface effect we will get the optimum ballast quantity as algebraic sum between full tanks, that, with a minimum quantity of sea water taken onboard can offer the stability and and the trim excluding and exclude the plastic deformations.

6. Conclusion

The ship ballasting, even it seems to be a very simple operation, have a big effect over the ship stability and over the operating conditions at the ship that have trips without cargo.

The optimization of the ballast operations can be approached from the point of fuel efficiency and as a ship operational efficiency. The optimum situation depends by the type of the ship, hull dimensions, hull forms, and the purpose of the ship or by the operating conditions. Optim poate reprezenta de fiecare dată

Talking about the maritime ships, after obtaining a good stability, we can consider as an optimum criteria the fuel efficiency getting a conveyable hull with the ballast, witch, at a given speed have a minimum drag force, and in that situation, a minimum fuel consumption.

References

1.Ceangă, V., Mocanu, C., Teodorescu C: *Dinamica sistemelor de propulsive,* Editura Didactică şi pedagogică, 2003, p. 671.

2.Popovici, O: *Calculul şi construcţia navei*, 1976, p 68.

3.Maier, V.: *Mecanica şi construcţia navei*. In:Editura tehnică, 1989, p. 493.

4.Macarie E: Referat nr 2 al tezei de doctorat, cercetări privind optimizarea balastării navelor comerciale, Universitatea Maritimă Constanţa, 2009, p. 117.

5.*** *SOLAS*, Consolidated Edition, International Maritime Organization 2001.