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SOFTWARE PLATFORM FOR HYDROSTATICS AND HYDRODYNAMICS PERFORMANCES ESTIMATION IN EARLY SHIP DESIGN

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ABSTRACT

Starting with early ship design stage, the hydrostatics and hydrodynamics performance estimation of the ship is an important issue. As a consequence, the PHP (Preliminary Hydrodynamics Performance) software platform was developed in the Research Centre of the Naval Architecture Faculty in "Dunarea de Jos" University of Galati, in order to obtain the preliminary evaluation of the ship resistance and powering performances, based on the main dimensions and fineness coefficients. Also, the practical estimation of the ship weight and initial transverse stability can be realised by using PHP software platform. A synthetical description of the theoretical aspects and software modules is presented in this paper. This software platform is used at the Naval Architecture Faculty, for didactical applications or research activities dedicated to the initial ship design stage.

Keywords: ship hydrostatics and hydrodynamics, initial design, software platform

1. INTRODUCTION

The early ship design process is very important in order to obtain the standard of hydrostatics and hydrodynamics performances ([6], [7]).

The evaluation of the main dimensions and fineness coefficients of the ship represents a first step, having a decisive impact on the ship performances. Different statistical relations can be used in order to verify the main dimensions and form coefficients of the ship.

Then, the correlation between the displacement and the weight components of the ship must be verified in the second stage and the position of centre of gravity may be estimated.

The next step consist of the preliminary estimation on initial transverse stability. The initial metacentre height can be calculated on the basis of difference between the vertical positions of the transverse metacentre and centre of gravity.

The following step is focused on the preliminary estimation of the ship resistance and powering performance, including the selection of the optimum propeller characteristics on the basis of B-Wageningen propeller series.

In the last preliminary hydrodynamic step, the manoeuvring performance of the ship must be estimated, by using the PHP-Manoeuvrability software platform.

A fast investigation procedure on initial transverse stability and hydrodynamics performance is an important problem of the early ship design stage. In this context, the PHP (Preliminary Hydrodynamics Performance) software platform was created in the Research Centre of the Naval Architecture Faculty in "Dunarea de Jos" University of Galati.

A synthetical description of the specific methods used to solve the mentioned problems is presented in the next chapter.

2. THEORETICAL ASPECTS

The hydrodynamics performance of the ship is influenced by the main dimensions and fineness coefficients. As a consequence, the selection of the length, breadth, draught and depth of the ship is very important and can be performed by using empirical relations ([13], [15], [17], [18]) or statistical data.

The ship length may be calculated as a function of the ship speed and displacement or volumetric displacement. For example, the relations of Jager, Noghid, Gallin or Posdunine can be applied ([6], [11]).

The breadth can be calculated depending of the type of ship and length between perpendiculars, by using the formulas of Arkenbout and Schokker, Watson, Sanderson or Bendford ([6], [11], [13], [17], [18]).

The mean draught can be estimated depending by the breadth-draught ratio. The depth depends by the length-depth ratio. The relations proposed by Watson are typically ([17], [18]).

Also, the empirical formulas can be applied in order to compute the fineness coefficients.

The block coefficient depends by the Froude number or ship speed and length between perpendiculars. The relations of Asik, Ayre, Alexander, Dawson and Silverleaf may be used ([6], [11]).

The water plane area coefficient depends by the block coefficient and can be calculated by using the relations of Lyndbladom, Bronikov, Parsons or Gallin ([6], [11], [14]).

Also, the midship section coefficient can be determined by means of the block coefficient, using the expressions of Noghid, Jeleajkov or Parsons ([6], [11], [14]).

The ship weight components may be estimated in the initial design stage in order to check the balance between the ship displacement and the main components. The ship displacement is divided into the light ship weight and deadweight. The main components of the light ship are: structural weight, propulsion system weight, outfit and hull engineering weight and displacement reserve. The main components of the deadweight are: payload weight, fuel weight including lube oil and fresh cooling water, crew and luggage weight, provisions and stores weight and water ballast weight ([6], [12]).

Different parametric models can be applied in order to compute the mentioned weights ([6], [12], [13], [14], [15], [17], [18]).

Also, the position of ship centre of gravity may be estimated. The vertical centre of gravity depends by the ship depth and the type of ship ([6]).

The preliminary estimation on initial transverse stability is a very important step in early design stage. In order to compute the initial metacentre height, the vertical centre of buoyancy and the transverse metacentre radius must be estimated ([6], [7], [13], [15], [17]).

The vertical centre of buoyancy can be estimated depending by mean draught and fineness coefficients, using different relations, as Riddlesworth, Asik, Noghid, Moorish, Pozdiunin-Lackenby, Wobig, Normand or Schneekluth ([6], [15]).

The transverse metacentre radius may be estimated depending by the ship breadth, mean draught and fineness coefficients, by using distinct expressions, as Normand, Hoovgard, Jakwlew or Ranert [6].

Also, direct expressions can be used in order to calculate the initial metacentre height ([6], [7]).

The next step is dedicated to the ship resistance and powering performance estimation. The selection of optimum propeller characteristics on the basis of B-Wageningen propeller series was included ([6], [7], [13], [14], [15], [17]).

The ship resistance represents the resulting hydro-aerodynamics forces acting on the ship, projected on the speed vector direction [7]. On this software platform, the resistance in still water of the ships running in displacement domain can be calculated, based on the Holtrop-Mennen method ([3], [4], [10].

By using this method, the total ship resistance can be determined on the basis of following relation ([3], [4])

$$R_T = R_F(1+k_1) + R_{APP} + R_W + R_B + R_{TR} + R_A \qquad (1)$$

where $(1+k_1)$ is the form factor of the bare hull, R_F is friction resistance, R_{APP} is appendages resistance (due to the rudders, fins, bilge keels, shaft brackets, bossings, bow thrusters tunnels, etc.), R_W is own wave resistance, R_B is the additional pressure resistance of bulbous bow near the water surface, R_{TR} is the additional pressure resistance due to transom immersion and R_A is model-ship correlation resistance.

Also, on the basis of Holtrop-Mennen method the propulsion coefficients may be estimated (wake fraction, thrust deduction coefficient and relative-rotative efficiency) and the hull efficiency can be calculated.

In order to determine the open water propeller efficiency and to calculate the quasi-propulsive coefficient, a software module was developed, based on the diagrams of B-Wageningen propeller series [10]. Knowing the propeller diameter, the blades number and the blade area ratio, the thrust and torque coefficients, the open water propeller efficiency, the pitch ratio and the propeller revolutions can be determined.

In the following step, the powering performance of the ship may be estimated, on the basis of a specific software module [10].

The effective power is calculated by using the relation ([10], [14])

$$P_E = R_T \cdot v \cdot (1 + M_D) \qquad (2)$$

where M_D is design margin and v is ship speed.

The delivered power is calculated by using the expression ([5], [9])

$$P_D = \frac{P_E}{\eta_D \cdot n_p} \qquad (3)$$

where η_D is quasi-propulsive coefficient and n_p is the propellers number.

The brake power at full rating (100% MCR) is given by the relation ([10], [14])

$$P_B = \frac{P_D}{\eta_{ax} \cdot \eta_{red} \cdot (1 - M_S)} \qquad (4)$$

where η_{ax} is the line shaft bearing efficiency, η_{red} is the reduction gear efficiency and M_S is the power service margin.

The brake power at service rating SR is given by the relation ([10], [14])

$$P_B^{SR} = \frac{P_B}{SR} \qquad (5)$$

The usual values of the service rating coefficient $SR = 0.85...0.95$ correspond to the domain 85%-95% MCR.

In the last preliminary hydrodynamic step, the manoeuvring performance of the ship must be estimated, by using the PHP-Manoeuvrability software platform.

On the basis of these modules, the hydrodynamic performance of the rudder, ship manoeuvring performance, ship sinkage in shallow water or bowthruster powering can be estimated. The detailed description of these modules was realised in the references [8] and [9].

As a consequence, the most important performances of the ship in the initial design stage can be estimated by using this complex software platform: the initial transverse stability, ship resistance, propeller characteristics, powering performance and manoeuvring abilities.

3. PHP SOFTWARE PLATFORM

The PHP software platform contains the following initial design modules (Fig.1): PHP Main Dimensions, PHP Ship Weight, PHP Transverse Stability, PHP Ship Resistance Holtrop-Mennen, PHP Propeller B-Wageningen, PHP Ship Powering.

Also, the PHP software platform contains the following manoeuvrability modules, that were described in the references [8] and [8]: PHP Rudder Hydro, PHP Rudder Cavitation, PHP Manoeuvrability Performance, PHP Squat and PHP Bowthruster.

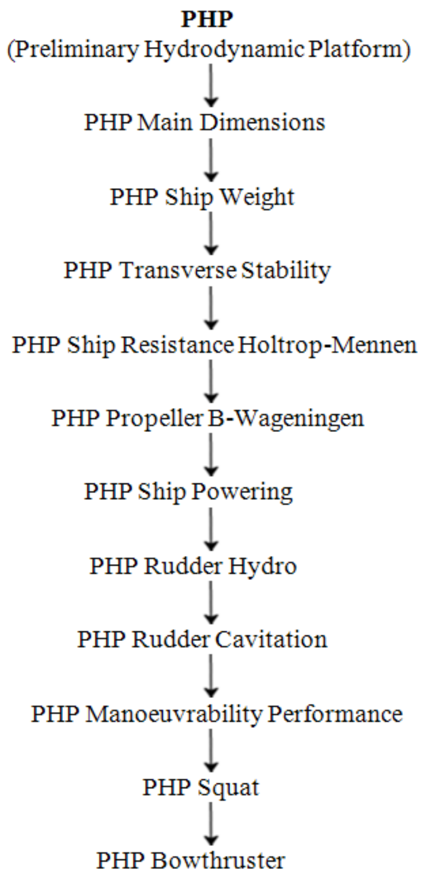

Fig.1. PHP software platform flow chart

The first module, PHP-Main dimensions calculates and check the main dimensions and fineness coefficients of the ship, on the basis of statistical or empirical relations.

The second module, PHP Ship Weight can be used in order to estimate the ship weight components.

The third module, PHP Transverse Stability allows to compute the initial metacentre height and to estimate the initial transverse stability of the ship.

The PHP Ship Resistance Holtrop-Mennen module estimates the ship resistance by using the mentioned method ([3], [4]).

The PHP Propeller B-Wageningen module allows to select and calculate the propeller characteristics on the basis of diagrams of B-Wageningen propeller series.

The PHP Ship Powering module can be used in order to compute the effective power, delivery power and brake power of the ship.

The PHP Rudder Hydro module calculates the position of the rudder stock to the leading edge and the total torque related to the rudder stock, by means of the Voitkounski method [16], in order to select the steering gear from data catalogues.

The PHP Rudder Cavitation module uses the Brix method [2] in order to check the cavitation domain on the rudder surface.

The PHP Manoeuvrability Performance module was developed to estimate the manoeuvring and course keeping characteristics of the ship, based on the linear hydrodynamic Abkowitz manoeuvring model [1] and relations of Lyster and Knights [5].

The PHP-Squat module can be used in order to estimate the ship sinkage in shallow water restriction [2].

The final module, PHP Bowthruster can be used to determine the bowthruster powering [2].

The software platform PHP is used for didactical applications at the Naval Architecture Faculty ([8], [10]) and also, for design or research activities related to the ship transverse stability and hydrostatics or hydrodynamics performance in the early design stage.

4. CONCLUDING REMARKS

Starting with the initial ship design stage, the hydrostatics and hydrodynamics performance estimation of the ship is an important issue.

In this context, the complex software platform PHP (Preliminary Hydrodynamics Performance) was developed in the Research Centre of the Naval Architecture Faculty in "Dunarea de Jos" University of Galati, in order to determine the main dimensions of the ship and fineness coefficients and to estimate the ship weight, initial metacentre height, ship resistance, powering and manoeuvring performances in initial design stage.

On the basis of PHP software platform, the most important initial design problems related to the hydrostatics and hydrodynamics performances can be solved:

- Determination and checking of the main dimensions and fineness coefficients of the ship;
- Preliminary estimation of the ship weight components;
- Preliminary estimation of the initial metacentre height and checking of the initial transverse stability;
- Preliminary estimation of the ship resistance by using Holtrop-Mennen method;
- Preliminary estimation of the propeller characteristics;
- Preliminary estimation of the powering performance of the ship;
- Estimation of the rudder stock position;
- Estimation of the total torque on the rudder stock and selection of the steering gear from data catalogue;
- Checking of the rudder cavitation;
- Estimation of the ship manoeuvring and course keeping abilities in deep water conditions;
- Estimation of the ship sinkage in shallow water conditions;
- Estimation the bowthruster power and selection of the bowthruster type from data catalogue.

This software platform is in current use at the Naval Architecture Faculty in "Dunarea de Jos" University of Galati, for didactical applications or research activities dedicated to the hydrostatics and hydrodynamics studies in the initial ship design stage.

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