Virtual Sea Polygon and Programming Aspects in Dynamic of Ships.

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ABSTRACT

There is discussion about mathematical methods, verification and structure of software for Virtual Sea Polygon (VSP) which is intended for strategic and operational analysis dynamics of ships in all possible scenarios of its exploitation. Scheme of software is reflected below. It reflects both algorithmic and mathematical angles for resolving this task. Database of ships has to be linked with VSP. VSP can be implemented into Decision Support System of ships.

Keywords

VSP (Virtual Sea Polygon), WWF (Wind and Wave Fields), DOS (Database of Ships), MDSS - Marine Decision Support System for dynamic of ships. SaaS – Software as a Service.

1. INTRODUCTION

VSP is an instrument for analysis of dynamic of ships during its passing through sea regions with different WWF [2,6]. Software uses linear and nonlinear mathematical models. This requires big processor resources for quick and adequate calculation of dynamic of ship. As usual on-boards computers can't have it. The way for resolving this can be offering this software in regime SaaS. In this case, the developer of VSP can install the software and manage them on distant computer, while the user will be given the opportunity to use the software VSP over the internet. The main advantage of this method is the lack of user costs for installation, maintenance and updating of software VSP. The quality factor of the software (soundness) [3,4] is that the program is reasonably and rationally implemented with a sound organization management and information. The quality factor of the pooling of resources within the VSP can be determined in particular by the following rules: clarity and visibility of information flows, good testability, tolerance and modifiable. Operator sequence should be structured so that unrelated information flow passed through various subsequences included in the source [4]. To assess the quality factor software can be used in some cases to the analyzers of programs such as OSA [5].

2. STRUCTURE OF VIRTUAL SEA POLYGON

To create a software package Virtual Sea Polygon represents mathematical block diagram of the software, which will allow to solve the problem at the same time. Mathematical block diagram is shown in Figure 1.1. A block diagram of the software virtual sea polygon consists of a total of twelve blocks. **Block 1** determines the velocity vector of the ship as the vector sum of own ship's speed and current vectors. The value is determined based on calculations made in block 5, according to the current's velocity at the position of the ship and the heading angle of the current. Ship's speed is determined as a function of engine power of ship N_{ship} and resistance of ship's movement R_{ship}, $V_{ship} = f(N_{ship}, R_{ship})$. Resistance of ship's movement at the bow R_{ship} - is calculated according to the **block 2** and the R_{ship} is defined as the term viscous, wave and aerodynamic resistance of ship's movement: $R_{ship} = R_{tc} + R_{wave} + R_{aerod}$.

Block 3 - mathematical block diagram of VSP is one of the main databases of VSP - database of ships (DOS). DOS is a relational database of ships, which has the ability to operate with VSP. In the following DOS the basic parameters of the ship are reflected: dimensions, weight, specific dimensions and volumes, based on the theoretical drawing, possible to calculate: the displacement volume - void coordinates of center of gravity (center of mass, center of magnitude) X_{ship}, Y_{ship}; water line area (WLA), central moments of inertia square I_x and I_f, coefficients of fullness, etc .; and axial moments of inertia of the ship I_x, I_y, I_z; coefficients of ship's resistance ($R_{tc}, R_{wave}, R_{aerod}$), which can be determined settlement, or full-scale model means; roughness of the ship, depending on the operating conditions and the condition of the surface of the ship; ship propulsion system parameters; engine characteristics (in particular - the propeller); decomposition of ship into compartments; loading of ship within the divisions: the crew, supplies, cargo, which determine the draft of the ship. Mathematical formulas for determining these parameters may be used on the basis of [1].

Block 4 - database of physical parameters of salt water and air in the internal waters of the rivers and the seas and the oceans, along the route of ships. The input data for the determination of the parameters are the air and water temperature, which in turn flows through the databases (NCEP / NOAA). Block 4a) consists of routines navigation (GPS / GLONASS) determining the ship's position at any given time, and routines Fairway, which determines the depth and dimensions of the fairway on the route of the ship. These parameters are reflected further on the use of the synthesizer block 8 and 9, the mathematical models to determine the dynamics of the ship. Block 5 - mathematical block diagram of VSP consists of routines that define the vector currents, wind and waves along the route of the ship. The input data is the data from the routine navigation required vectors based on data from the database NCEP / NOAA through the Cloud technology.

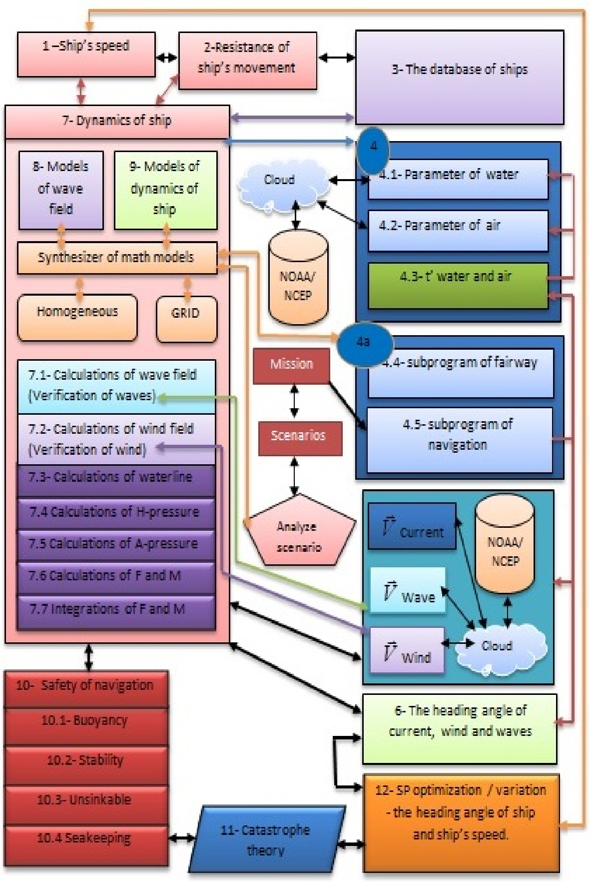


Fig. 1.1. Mathematical block diagram of the virtual sea polygon for a single processor mode and cluster mode (GRID)

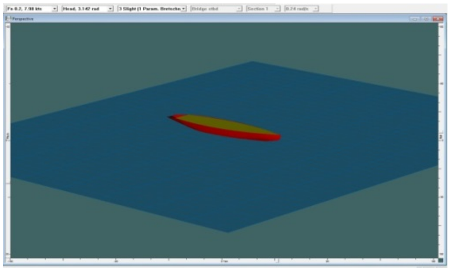
Block 6 is a subprogram for calculating the heading angle of the ship and accordingly, angle of currents, wind and waves. These parameters are input to the unit for the calculation of wind and wave fields and the dynamics of ship. **Blocks 7, 8, 9** are the basic building blocks modeling directly wind-wave field and the dynamics of ship. **Block 8** - contains models of wind and wave fields. **Block 9** - models for calculating the dynamics of the ship under various scenarios. **Block 7** - is calculating the dynamics of the ship under the influence of wind and wave fields. There should be continuous and correct interaction of these modules, which occurs with the participation of the logical - linguistic to analyzer of scenarios and to synthesizer of circuit calculations. **Block 7.1.** - The subprogram for calculating the dynamics of the ship under the influence of wind and wave fields performing the following steps: 1 - Select the grid water area of navigation of the ship; 2 - generation wave field; 3- calculation of geometry and derivatives of the potential on the surface of the waves; 4 - Definition of wave angle; 5 - verification of the wave height and the resulting calculated from the block 5 - subprogram of wave; 6-adjustment model of wind and wave fields. **Block 7.1**. It is used to calculate wind wave field- one of the models presented in **block 8**. Using of the analyzer based on the data shown in Table. 1.1. - Modeling of the dynamics of the ship into VSP on the irregular waves. Logico-linguistic concepts related to modeling the dynamics of ship. And complement simulation dynamics of ship on regular waves.

Table. 1.1. Features of irregular wave time history of sea.

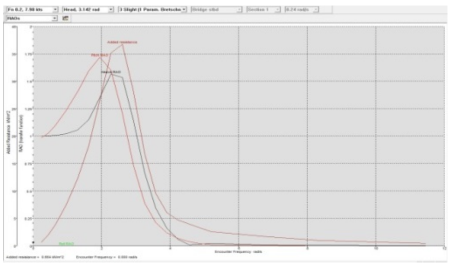
№	Parameter Description
1	Average amplitude measured on the set of waves;
2	Average height measured on the set of waves;
3	Average wave period measured between successive peaks of many waves;
4	Average wave period measured between successive depressions many waves;
5	Average wave period measured between consecutive rising zero point of many waves
6	Average wave period measured between successive zero points downward many waves
7	The average period of many waves
8	The modal wave period
9	The average of the highest third of the amplitudes or substantial (significant) amplitude.
10	The average of the highest third of the height or substantial (significant) height. Wave height of 33% of the supply.
11	Deviation surface elevation relative to the mean square;
12	Level deviation to the average surface elevation of the square root.

Block 7.2 calculate the wind field on the basis of the available water area of the grid in GRIB format, the strength and direction of wind, calculated from the block 5 - subprogram of wind. **Block 7.3** - Calculation the line of intersection of the surface wave and the ship's hull. **Block**

7.4 - Calculation the hydrodynamic pressure at the wetted surface of the hull. **Block 7.5.** - Calculation of the aerodynamic pressures on the surface of the hull above the water. **Block 7.6.** - Calculation of the disturbing and restoring forces and moments. **Block 7.7.** - The integration of forces and moments on the ship's hull. Fig. 1.2 shows typical screen shots of wind-wave imaging of the sea surface and the dynamic position of the ship, and graphs derived from calculations of the dynamics ship. Froude number allows comparison of wave conditions for ships of different sizes. In the figure above Froude number = 0.2 indicates a large displacement ship. Energy distribution irregular wave - wave spectrum describes the distribution of wave energy (amplitude, wave height) depending on the frequency. Response amplitude operator (RAO) shows how to respond to fluctuations in the ship depending on the frequency of meetings with the wave. In the above graph (Figure 1.2. b) it is clear that the resistance at 0 - zero frequency (0.00 rad / s - radians per second) of 0.664 kN / m. As the collision frequency wave is the wave resistance increases and reaches a maximum (37 kN / m.) At a frequency of 2.5 rad / s, which corresponds to the period of the incident wave - 2.72 seconds. Further decreases sharply at a frequency and - 4 rad / s, of 5.7 kN / s. Further there is a shallow fall wave resistance meeting with increasing frequency of the ship and the waves. In this case, this frequency is 2.5 rad / s. Roll (roll), given that the waves run - is virtually nonexistent.



a) Screenshot of the visualization: the sea state 3 points wave heading angle of 180 degrees. - Counter the wave speed of the ship - 7.98 knots, the Froude number 0.2.



b) Wave resistance (added resistance) and response amplitude operator pitch, heave and roll, depending on the frequency of collisions of ships with the incoming wave (Encounter Frequency)

Fig. 1.2. Visualization of wind and wave fields (a) and dynamics of the ship (b)

Heave and pitch have response amplitude operator (RAO) and equal to one at the start of the schedule, increase sharply and reaches a maximum (1.75 - 1.85) at frequencies of encounter 2-2.5 rad / p. Next there is a sharp drop down to zero since the frequency - 4-5 rad / s. If response amplitude operator is equal to one (RAO = 1), physically, this means that at a given frequency the ship behaves like a cork, that is, It moves up and down with the wave. It is obvious that much different picture obtained using models of regular and irregular waves. The advantage is the ability to combine the VSP of physical and mathematical models to reproduce adequate wind and wave fields and the dynamic behavior of the ship in conditions as close to real. It provides the basic blocks 7, 8, 9.

Block 10 is mathematical block of VSP constitute the basic routines that determine the safety of navigation: buoyancy, stability, unsinkable and seakeeping. Comparison criteria of safe navigation should be carried out throughout all calculations from the ship at the port of loading in order not to go beyond the permissible scope of security. **Block 11** is included in the VSP, in connection with the intensive development of this direction [2] associated with the use of computer simulations of disaster prevention in the MDSS - marine decision support system. This block is a similar system, which in addition to the block 10 prompts the operator to analyze possible options VSP before the catastrophic events. **Block 12** is a subprogram of variation and optimizing ship’s speed and heading angle, as the parameters of the greatest impact on the dynamics of the ship. This unit is a purpose to perform a variation of speed and heading angle and to predict the most appropriate action in each situation.

3. CONCLUSION

The above software method shows the program-mathematical core of VSP, which is the main objective of this study. Presented VSP lets use it into the ship on boards computers for analysis dynamic of ship behavior in different wave and wind conditions. The main advantage of presented software is its possibility to be reliable verified on the rotes of ships, using hydrometeorology prediction from database NCEP/NOAA and possibility to be divided for using distant power computer together with on board Marine Decision Support System.

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