



## PREDICTION FOR ROLL AND ROLL CROSS-VERTICAL OSCILLATORY MOTIONS OF THE SHIP IN THE REAL SEA, USING OCTOPUS

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**Abstract:** A ships designer have the responsibility of developing the design methodologies and construction technologies, which, based on the actions exhibited by the natural environment under the hull, allow performing operation, adequate to the ship proper functionality. The complications arising from the problematic of the general motions of the ship sailing under real sea, establish the needs for anticipation in the functional performance of the ships in real sea navigation, since the early stages of design, the motivation being dictate by the need to reduce design time and cost of construction.

This paper presents a study on roll motions of a platform supply vessels in hydrometeorological conditions of navigation of the Mediterranean Sea. Geometrical, constructive and hydrodynamic particularities of these special vessels make interesting and also necessary - for safety of the navigation and operation of the ship - a study for the roll movements. The content of the paper offer a study of simple roll compared to the simple vertical oscillations. The study provides comparative information regarding RAO (Response Amplitude Operator) operator of the ship for the position, velocity and acceleration of the indicated points belonging hull, in the incident wave systems in the Mediterranean Sea, interpreted by the Jonswap energy spectrum. There will also be highlighted compared the answers of the ship for the points of interest, depending on the characteristics of the incident waves (significant height of the wave, wave period, pulsation of the wave). The study takes into account both types of oscillation (simple roll and simple vertical motion), for different positioning of the vessel in relation to front of the waves, showing the recommended position (favorable) and avoided (unfavorable). Was not neglected in the study the interpretations regarding the shear forces and bending moments at points of interest chosen, depending on the characteristics of the incident waves and the ship's position in relation to them.

For the study, were used features as a tool for modeling and simulation offered by OCTOPUS / SEAWAY - software that allows the study of the computerized behavior of the ship on the waves in the real sailing

conditions. Program library was used for both the vessel itself and navigation modeling environment, for regular waves as well for the irregular waves which was modeled using Jonswap energy spectrum.

**Keywords:** simple roll and roll cross-vertical motions; platform supply vessel; wave energy spectrum; RAO; simulation; shear forces and bending moments; OCTOPUS / Seaway.

### 1. INTRODUCTION

Description of behavior of the ship body in real navigation conditions is a difficult problem. The solutions are difficult to find and are conditioned by the various and complexe perturbation parameters actions of different grades.

During the time, a significant number of researcher in naval architectural domain try to find some answers.

In developing the theoretical support for a ship behavior in the real sea, a significant contribution has brought Prof. T. Fossen, in his book “*Guidance and Control of Ocean Vehicles*” [5], contribution which involved:

- independent analysis of the various phenomena and changes due to external disturbances, insisting on the ways of coupling the motions of translation and rotation;

- use superposition principle in assessing the irregular and random behavior of the navigation environment;

- application of modern analytical mechanics to determine the inertia matrices and complementary;

- reasoned explanation of the additional mass concept and theoretical process of the related phenomena; adaptation and improvement " strip theory " for use in resolving the issues raised by the determination of hydrodynamic coefficients involved in the equation of motion of the ship.

In Romania, Prof. L. Domnișoru is an important author for naval architectural domain. His book “*Ship dynamics. Oscillations and vibrations of the ship hull*” [3], is focused on the fundamental problems of ship dynamics, concerning the

oscillations and vibrations of the ship hull in waves. The author accomplish, in his book, a unified approach of the main phenomenon and theoretical models for the analysis of ship dynamics in real sea, oscillations and vibrations, linear and non-linear, determinist and statistic. The author had an important contribution in order to make possible an easier way to understand and to learn the mentioned topics, by presenting some examples with eigen programs, concerning the transposing procedure af analytical methods for the analysis of ship dynamic in waves, into numerical models useful to the naval architect.

Romanian researchers have contributed in the field of spectral analysis of the wave regime, and for the Black Sea, Trușcă developed, in 2005, a wave spectrum based on the model SWAN (Simulation of Waves Nearshore) developed at the Delft Technical University in the Netherlands.

## 2. THEORETICAL CONSIDERATIONS

In 1950, the Society of Naval Architects and Marine Engineers (SNAME) are imposed the symbols and definitions for the linear and angular coordinates of the ship motions also for the forces and moments which actions on the ship during the navigation on the real sea [3], [5].

Therefore, the general equations of motion of the ship, considered as rigid with six degrees of freedom, can be written using vectors:

$$\begin{cases} \eta = [\eta_1^T & \eta_2^T]^T & \eta_1 = [x & y & z]^T & \eta_2 = [\varphi & \theta & \psi]^T \\ v = [v_1^T & v_2^T]^T & v_1 = [u & v & w]^T & v_2 = [p & q & r]^T \\ \tau = [\tau_1^T & \tau_2^T]^T & \tau_1 = [X & Y & Z]^T & \tau_2 = [K & M & N]^T \end{cases} \quad (1)$$

where:

-  $\eta$  is the position vector of any point on the ship, expressed in relation to the fixed reference system, with the coordinates:  $\eta_1$ , vector of the linear coordinates which is characteristic for the translational movement;  $\eta_2$ , vector of the angular coordinates which is characteristic for the rotational movement;

-  $v$  is the velocity vector of any point on the ship, expressed in relation to the fixed reference system, with the coordinates:  $v_1$ , vector of the linear velocities, which is characteristic for the translational movement;  $v_2$  vector of the angular velocities which is characteristic for the rotational movement;

-  $\tau$  is the vector of forces and moments acting on the vessel at the point considered, expressed in relation to the fixed reference system, with the coordinates:  $\tau_1$ , vector of forces;  $\tau_2$ , vector of moments.

In the study of general movements of the ship, considered as a free rigid, it is used two reference systems:

The mobile reference system. Noted  $GX_GY_GZ_G$  is integral with the ship, originating in the center of gravity, G, of it. Axes – longitudinal,  $GX_G$  positive toward the bow, transverse,  $GY_G$ , positive to starboard; vertical  $GZ_G$ , positive to ship's keel - are central axes of inertia of the ship mass.

The fixed reference system. Noted  $OX_0Y_0Z_0$ , is considered inertial, with the origin, O, in the plane of the free surface of the calm water (without waves). The axes have the directions and senses same with the mobile reference system, for the rest position of the ship.

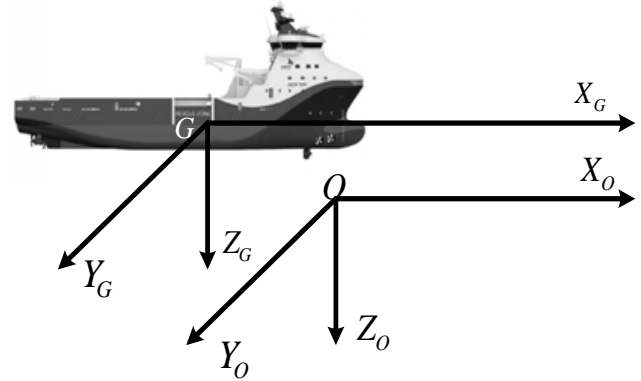


Fig. 1. Reference systems

Ship deviation from the equilibrium position, at a time, t, lead to changes in the relative position of the two co-ordinate systems.

The position and orientation of any point on the ship, at the time, t, with respect to the fixed reference system can be specified by six independent coordinates: three are linear and described translational movements; three are angular and described rotational movements.

In agreement with the notation established in Newtonian mechanics [7], translational and rotational motions of a free rigid are given by the relations:

$$F_p = m(\dot{v}_p + \omega \times v_p + \dot{\omega} \times r_{PG} + \omega \times (\omega \times r_{PG})) \quad (2)$$

$$M_p = I_p \dot{\omega} + \omega \times (I_p \omega) + m r_{PC} \times (\dot{v}_p + \omega \times v_p) \quad (3)$$

The general equation of motion of the ship, in a vector form, referred to the moving reference system, takes the form:

$$M\dot{v}_r + C(v_r)v_r + D(v_r)v_r + g(\eta) = \tau_M + \tau \quad (4)$$

where:

$v_r = v - v_C$ , relative velocity vector;

$\dot{v}_r$ , relative acceleration vector;

$$v = [v_1^T \quad v_2^T]^T = [u \quad v \quad w \quad p \quad q \quad r]^T,$$

overall velocity vector of the ship;

$$v_c = \begin{bmatrix} v_{2c}^T & v_{2c}^T \end{bmatrix}^T = \begin{bmatrix} u_c & v_c & w_c & 0 & 0 & 0 \end{bmatrix}^T,$$

overall velocity vector of marine currents;

$$\eta = \begin{bmatrix} \eta_1^T & \eta_2^T \end{bmatrix}^T = \begin{bmatrix} x & y & z & \varphi & \theta & \psi \end{bmatrix}^T,$$

position vector of an arbitrary point belonging to the vessel;

$g(\eta)$ , generalized vector of restored forces and moments;

$\tau$ , generalized vector of the disruptive forces and moments due to operations control and manoeuvre executed with the propulsion and steering systems;

$\tau_r$ , generalized vector of the disruptive forces and moments generated by the currents and waves on the wetted surface of the hull respectively by the action of the wind on the sail area of the vessel;

$M$ , the matrix of the ship mass inertia and additional water masses;

$C(v_r)$ , complementary matrix for the ship motions and additional water masses;

$D(v_r)$ , the damping matrix determined by the dynamic action of the water on the ship surface caused by the moving of the vessel.

The general equation of motion of the ship, in a vector form, referred to the fixed reference system, takes the form:

$$\begin{aligned} M_\eta(\eta)\ddot{\eta} - C_\eta(v_r, \eta)\dot{\eta} + D_\eta(v_r, \eta)\dot{\eta} + g_\eta(\eta) = \\ = \tau_{M\eta}(\eta) + \tau_\eta(\eta) \end{aligned} \quad (5)$$

In writing equation took into account the transformation matrix,  $J(\eta)$ , which allows to establish the relationship between the position vectors,  $\eta$  and velocities,  $v_r$ , so:

$$\begin{cases} \dot{\eta} = J(\eta)v_r \\ \ddot{\eta} = J(\eta)\dot{v}_r + \dot{J}(\eta)v_r \end{cases} \quad (6)$$

$$\begin{cases} v_r = J^{-1}(\eta)\dot{\eta} \\ \dot{v}_r = J^{-1}(\eta)[\dot{\eta} - J(\eta)J^{-1}(\eta)\dot{\eta}] \end{cases} \quad (7)$$

where the notation has been made:

$$\left\{ \begin{aligned} M_\eta(\eta) &= J^{-T}(\eta)MJ^{-1}(\eta) \\ C_\eta(v_r, \eta) &= J^{-T}(\eta)[C(v_r) - MJ^{-1}(\eta)J(\eta)]J^{-1}(\eta) \\ D_\eta(v_r, \eta) &= J^{-T}(\eta)D(v_r)J^{-1}(\eta) \\ g_\eta(\eta) &= J^{-T}(\eta)g(\eta) \\ \tau_{M\eta}(\eta) &= J^{-T}(\eta)\tau_M \\ \tau_\eta(\eta) &= J^{-T}(\eta)\tau \end{aligned} \right. \quad (8)$$

### 3. MODEL CONSTRUCTION

The model for the case study was constructed following the next relevant parameters:

a) OCTOPUS software

OCTOPUS-OFFICE 6 “BASIC” is used to calculate the transfer functions of ship responses in waves (absolute and relative motions, velocities, accelerations, hull girder loads and linear combinations of responses). The program has a built-in geometry modeller to prepare 2D- and 3D-models as input for the hydrodynamic calculations (2D-strip theory or a 3D-diffraction database can be used). Nonlinear sea state dependent transfer functions are solved by means of stochastic linearization. The program features extensive possibilities for graphical and textual reporting and presentation, including export functions to MS Word and Excel [9].

b) geometrical and constructive particularities for the ship

For the case study was chosen a PSV vessel type. A Platform supply vessel (often abbreviated as PSV) is a ship specially designed to supply offshore oil platforms. These ships range from 20 to 100 meters in length and accomplish a variety of tasks. The primary function for most of these vessels is transportation of goods and personnel to and from offshore oil platforms and other offshore structures.

In the recent years a new generation of Platform Supply Vessel entered the market, usually equipped with Class 1 or Class 2 Dynamic Positioning System.

OCTOPUS is a new and powerful instrument which is recently used for the navigation purposes. The software contains several utility programs exclusively naval, conducted by AMARCON (Advanced Maritime Consulting) in Netherlands. Includes routines for specific areas of interest, allowing the study of the behaviour witnessed ship on the waves.

The ship has a hull without bulbous in bow and aft in mirror; the construction of rudder post adequate of making a semi suspended rudder with weld caisson, semicompensed, with hydrodynamic profile, done in middle plane.

The principal dimensions are: length  $L = 58.636$  m, width  $B_x = 12.977$  m, draught  $T = 5.74$  m; mass 2992.747 t; dynamic mechanical particularities: service speed  $v = 11.3$  knots; chain of propulsion is made by propeller with 4 fixed blades, dispose in the middle plane (having the diameter  $D = 4.23$  m, pitch ratio  $P/D = 0.6$  and disk ratio  $A_E/A_0 = 0.57$  at speed  $n = 127$  rot/min), an axial line with speed reducer and one medium speed engine 6L52/55A, in four time, reversible, with supercharge and direct

injection, having nominal power  $P=6100$  Hp and rpm  $n=127$ .

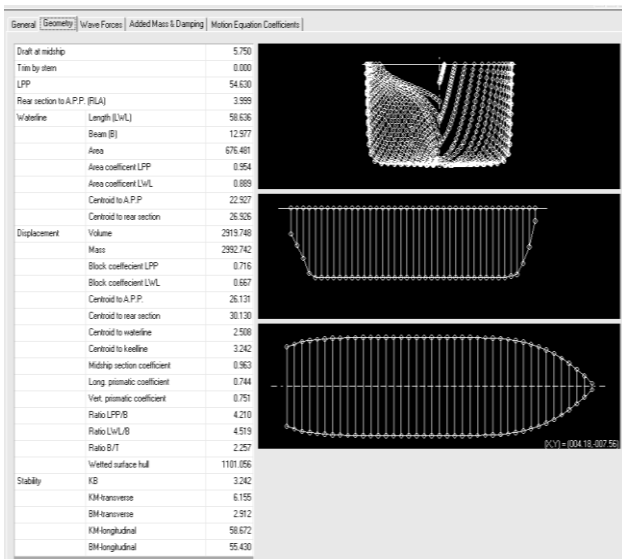


Fig. 2. The body line of the ship

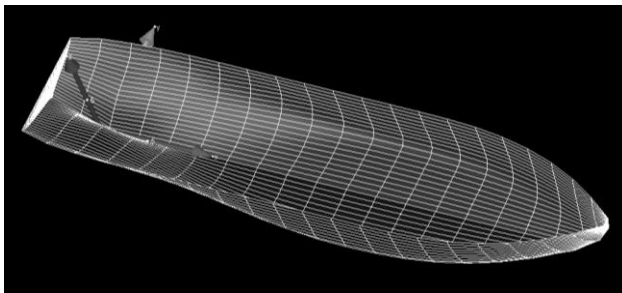


Fig. 3. The mesh shape of the ship

c) the navigation environment

In assessing the degree of agitation and irregularity of the sea, particularly interested in the statistical analysis of the elements "visible" or "apparent" wave like apparent height or apparent period, and the components of "invisible" such as operator RAO (response amplitude), the average height of the waves, their frequency or percentage achieving the repeatability of these heights average in total number of time intervals considered.

Thus, in international practice, use the following indicators, essential for assessing the intensity of the various schemes of agitation of the sea [2]: wave height with 3% insurance,  $\tilde{h}_{3\%}$ ; significant height,  $\tilde{h}_{1/3}$ ; average wave period,  $\tilde{T}_m$ ; energy spectra for two-dimensional (plane) waves,  $S(\omega)$ , respectively for three-dimensional (spatial) waves,  $S(\omega, \varphi)$ .

The Mediterranean Sea is characterized by waves with height  $\tilde{h} = 3m$ , length  $\tilde{\lambda} = 74m$  apparent velocity  $c = 11,5m/s$ .

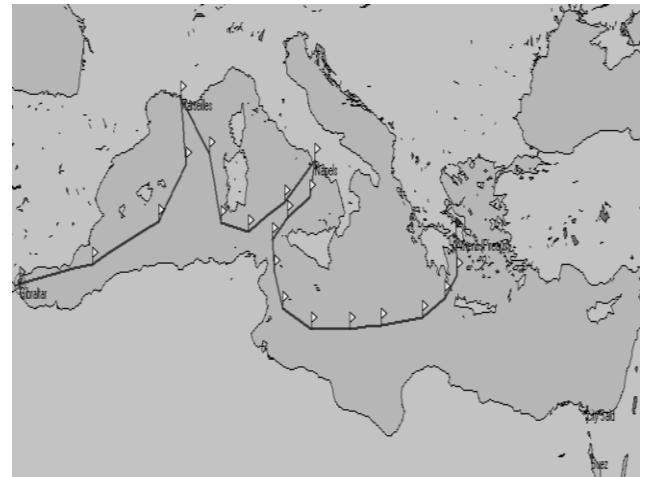


Fig. 4. The route of navigation

For the case study was elected a route of navigation starting Gibraltar Stream, to Marseilles and Naples Port, until Athens Port.

In describing the degree of agitation of the sea, the JONSWAP wave spectrum was chosen.

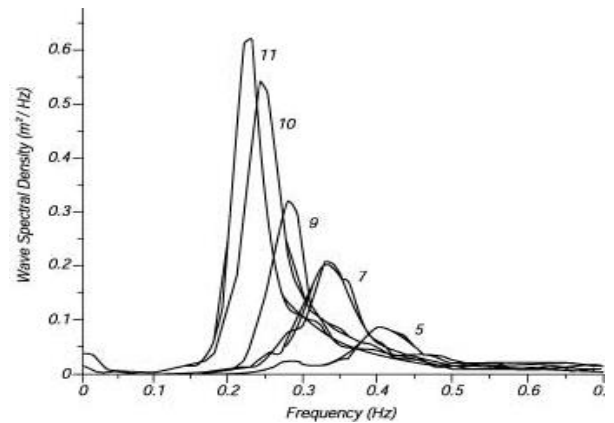


Fig. 5. The average JONSWAP wave spectrum

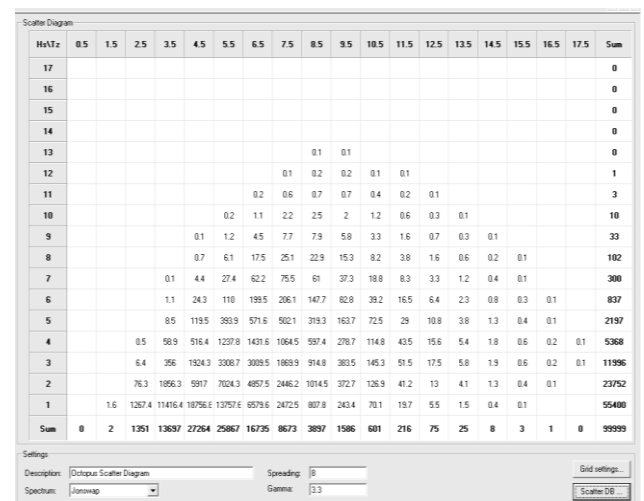


Fig. 6. The Sea spread provided by Data Base of OCTOPUS software for the navigation route

Irregular surface navigation environment resulted in superposition of 15 regular-type cosine waves with

significant heights between 0.96 and 23.89 m, respectively, zero crossing periods between 3.5 and 17.5 sec.

Testing program was made for a number of 5 ship speed: 0; 2.8; 5.7; 8.5 and 11.3 knots. The angle of incidence of ship waves was elected from 0 to 180 deg whith a step-variation of 10 deg.

#### 4. RESULTS AND DISCUSSION

For the study was considered the ecuation (5) into a explicite form

$$\begin{cases} a_{11}\ddot{X} + b_{11}\dot{X} + c_{11}X + a_{12}\ddot{Y} + b_{12}\dot{Y} + c_{12}Y + a_{13}\ddot{Z} + b_{13}\dot{Z} + c_{13}Z + \\ a_{14}\ddot{\varphi} + b_{14}\dot{\varphi} + c_{14}\varphi + a_{15}\ddot{\theta} + b_{15}\dot{\theta} + c_{15}\theta + a_{16}\ddot{\psi} + b_{16}\dot{\psi} + c_{16}\psi = R_x \\ a_{21}\ddot{X} + b_{21}\dot{X} + c_{21}X + a_{22}\ddot{Y} + b_{22}\dot{Y} + c_{22}Y + a_{23}\ddot{Z} + b_{23}\dot{Z} + c_{23}Z + \\ a_{24}\ddot{\varphi} + b_{24}\dot{\varphi} + c_{24}\varphi + a_{25}\ddot{\theta} + b_{25}\dot{\theta} + c_{25}\theta + a_{26}\ddot{\psi} + b_{26}\dot{\psi} + c_{26}\psi = R_y \\ a_{31}\ddot{X} + b_{31}\dot{X} + c_{31}X + a_{32}\ddot{Y} + b_{32}\dot{Y} + c_{32}Y + a_{33}\ddot{Z} + b_{33}\dot{Z} + c_{33}Z + \\ a_{34}\ddot{\varphi} + b_{34}\dot{\varphi} + c_{34}\varphi + a_{35}\ddot{\theta} + b_{35}\dot{\theta} + c_{35}\theta + a_{36}\ddot{\psi} + b_{36}\dot{\psi} + c_{36}\psi = R_z \\ a_{41}\ddot{X} + b_{41}\dot{X} + c_{41}X + a_{42}\ddot{Y} + b_{42}\dot{Y} + c_{42}Y + a_{43}\ddot{Z} + b_{43}\dot{Z} + c_{43}Z + \\ a_{44}\ddot{\varphi} + b_{44}\dot{\varphi} + c_{44}\varphi + a_{45}\ddot{\theta} + b_{45}\dot{\theta} + c_{45}\theta + a_{46}\ddot{\psi} + b_{46}\dot{\psi} + c_{46}\psi = M_x \\ a_{51}\ddot{X} + b_{51}\dot{X} + c_{51}X + a_{52}\ddot{Y} + b_{52}\dot{Y} + c_{52}Y + a_{53}\ddot{Z} + b_{53}\dot{Z} + c_{53}Z + \\ a_{54}\ddot{\varphi} + b_{54}\dot{\varphi} + c_{54}\varphi + a_{55}\ddot{\theta} + b_{55}\dot{\theta} + c_{55}\theta + a_{56}\ddot{\psi} + b_{56}\dot{\psi} + c_{56}\psi = M_y \\ a_{61}\ddot{X} + b_{61}\dot{X} + c_{61}X + a_{62}\ddot{Y} + b_{62}\dot{Y} + c_{62}Y + a_{63}\ddot{Z} + b_{63}\dot{Z} + c_{63}Z + \\ a_{64}\ddot{\varphi} + b_{64}\dot{\varphi} + c_{64}\varphi + a_{65}\ddot{\theta} + b_{65}\dot{\theta} + c_{65}\theta + a_{66}\ddot{\psi} + b_{66}\dot{\psi} + c_{66}\psi = M_z \end{cases}$$

For the roll motions are retained only the fourth row from the (9) equations (see the (10) equations) and for the heave motions are retained only the third row from the same equation (see the (11) equation). When the roll cross-vertical motions are study, both

the third and fourth rows are considered (see the (12) equation).

$$\begin{cases} a_{41}\ddot{X} + b_{41}\dot{X} + c_{41}X + a_{42}\ddot{Y} + b_{42}\dot{Y} + c_{42}Y + a_{43}\ddot{Z} + b_{43}\dot{Z} + c_{43}Z + \\ a_{44}\ddot{\varphi} + b_{44}\dot{\varphi} + c_{44}\varphi + a_{45}\ddot{\theta} + b_{45}\dot{\theta} + c_{45}\theta + a_{46}\ddot{\psi} + b_{46}\dot{\psi} + c_{46}\psi = M_x \end{cases} \quad (10)$$

$$\begin{cases} a_{31}\ddot{X} + b_{31}\dot{X} + c_{31}X + a_{32}\ddot{Y} + b_{32}\dot{Y} + c_{32}Y + a_{33}\ddot{Z} + b_{33}\dot{Z} + c_{33}Z + \\ a_{34}\ddot{\varphi} + b_{34}\dot{\varphi} + c_{34}\varphi + a_{35}\ddot{\theta} + b_{35}\dot{\theta} + c_{35}\theta + a_{36}\ddot{\psi} + b_{36}\dot{\psi} + c_{36}\psi = R_z \end{cases} \quad (11)$$

$$\begin{cases} a_{41}\ddot{X} + b_{41}\dot{X} + c_{41}X + a_{42}\ddot{Y} + b_{42}\dot{Y} + c_{42}Y + a_{43}\ddot{Z} + b_{43}\dot{Z} + c_{43}Z + \\ a_{44}\ddot{\varphi} + b_{44}\dot{\varphi} + c_{44}\varphi + a_{45}\ddot{\theta} + b_{45}\dot{\theta} + c_{45}\theta + a_{46}\ddot{\psi} + b_{46}\dot{\psi} + c_{46}\psi = M_x \\ a_{31}\ddot{X} + b_{31}\dot{X} + c_{31}X + a_{32}\ddot{Y} + b_{32}\dot{Y} + c_{32}Y + a_{33}\ddot{Z} + b_{33}\dot{Z} + c_{33}Z + \\ a_{34}\ddot{\varphi} + b_{34}\dot{\varphi} + c_{34}\varphi + a_{35}\ddot{\theta} + b_{35}\dot{\theta} + c_{35}\theta + a_{36}\ddot{\psi} + b_{36}\dot{\psi} + c_{36}\psi = R_z \end{cases} \quad (12)$$

According to the ship external and internal loads and to the sea state, the values for the forces  $R_X; R_Y; R_Z$  moments  $M_X; M_Y; M_Z$  for the coefficients

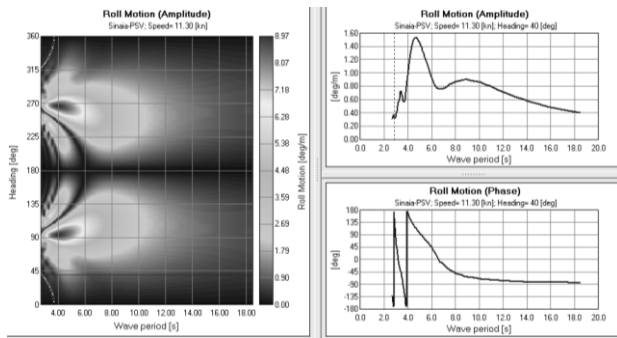
$a_{i,j}; b_{i,j}; c_{i,j}$   $i = \overline{1,6}; j = \overline{1,6}$  are indicated into the Basa Date of the OCTOPUS software.

Determination of the  $a_{i,j}; b_{i,j}; c_{i,j}$   $i = \overline{1,6}; j = \overline{1,6}$  coefficients is a delicate and challenging issue that raises many difficulties.

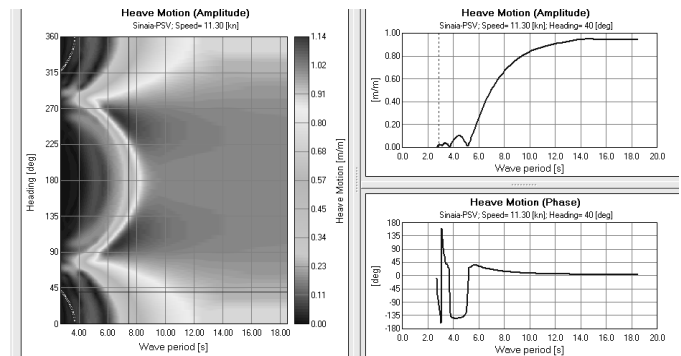
Also, estimation of forces  $R_X; R_Y; R_Z$  and moments  $M_X; M_Y; M_Z$  that action on the vessel is doable if is not known the weights distribution diagrams and charts aboard Archimedes thrust.

Into the following diagrams was indicated:

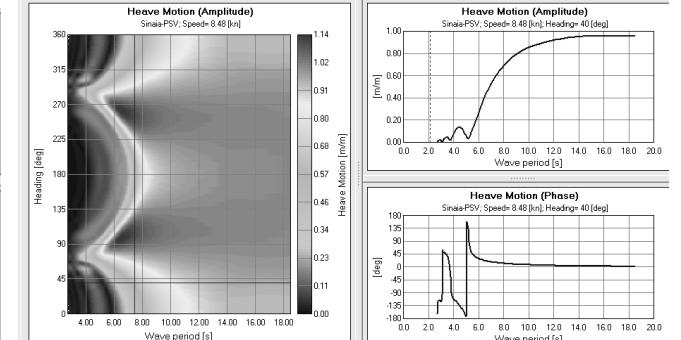
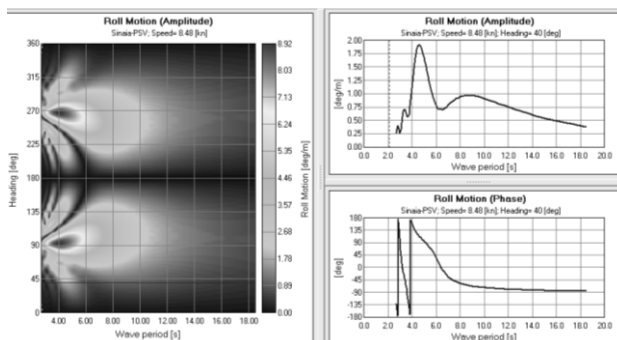
#### ROLL MOTION



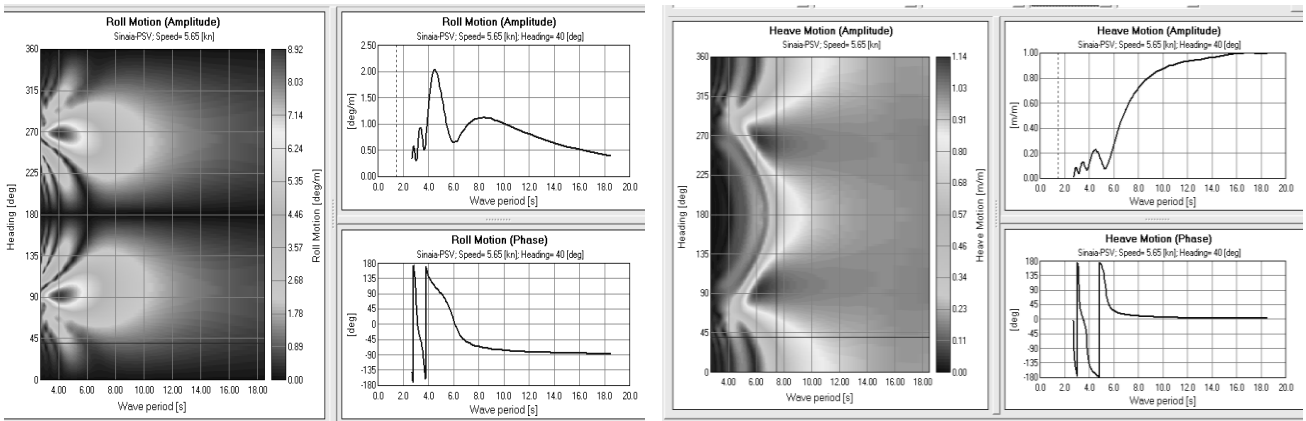
#### HEAVE MOTION



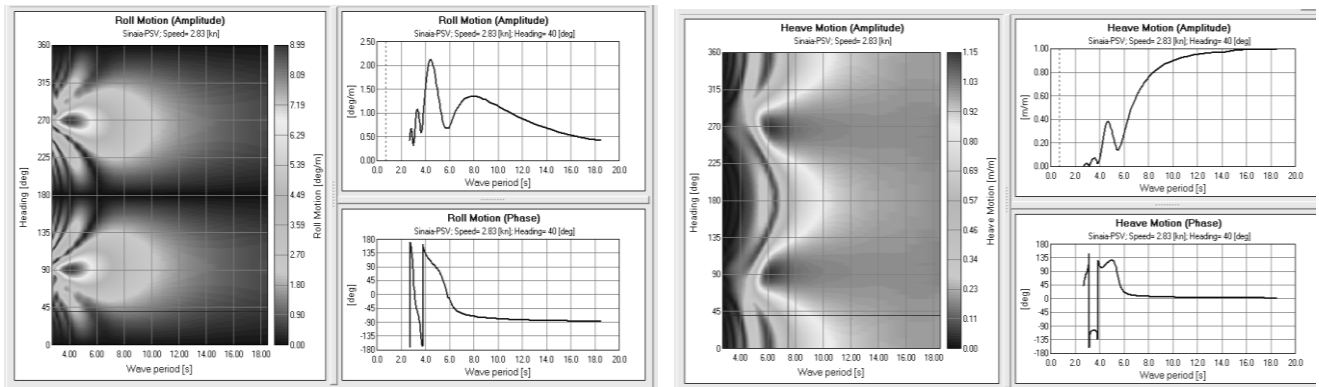
Encountering angle - 40 deg; ship speed - 11.3 kn



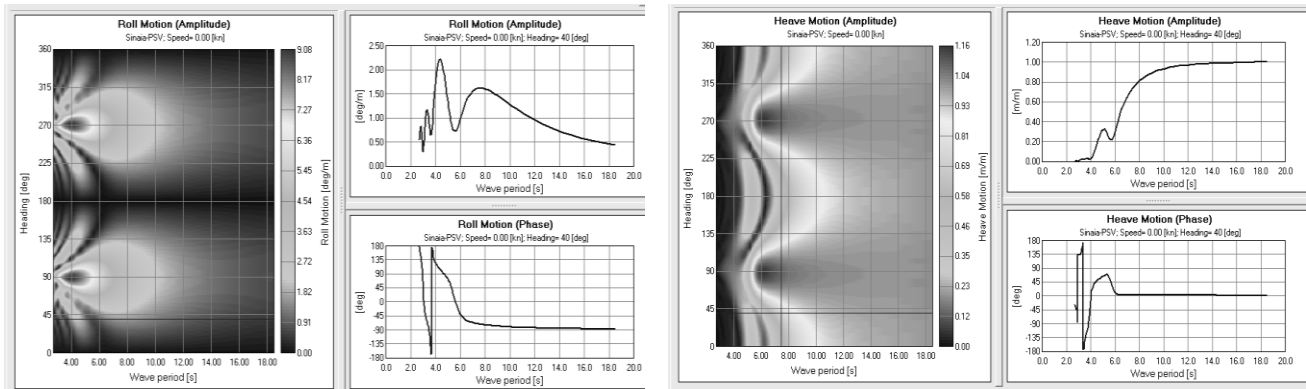
Encountering angle - 40 deg; ship speed - 8.5 kn



Encountering angle - 40 deg; ship speed – 5.65 kn



Encountering angle - 40 deg; ship speed – 2.83 kn

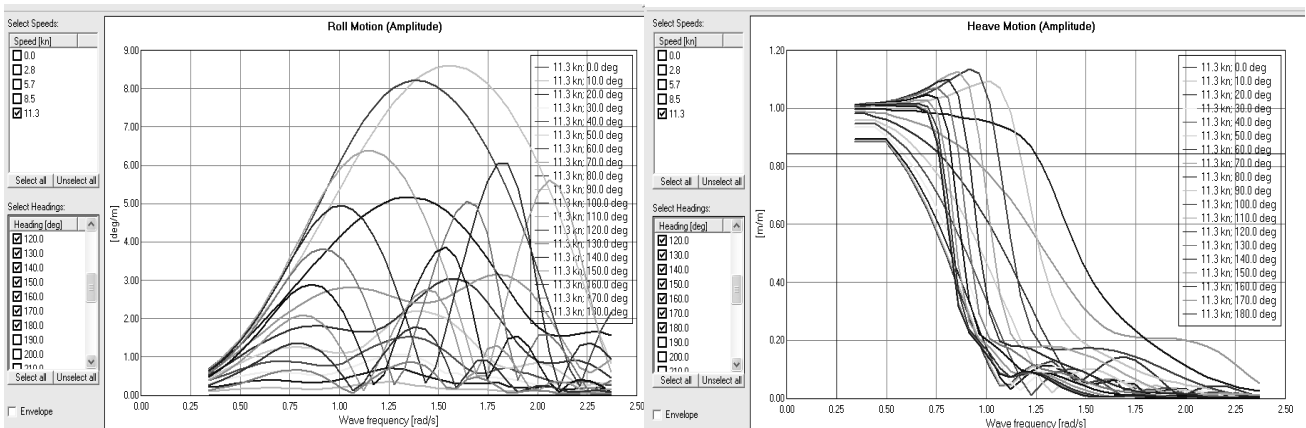


Encountering angle - 40 deg; ship speed – 0 kn

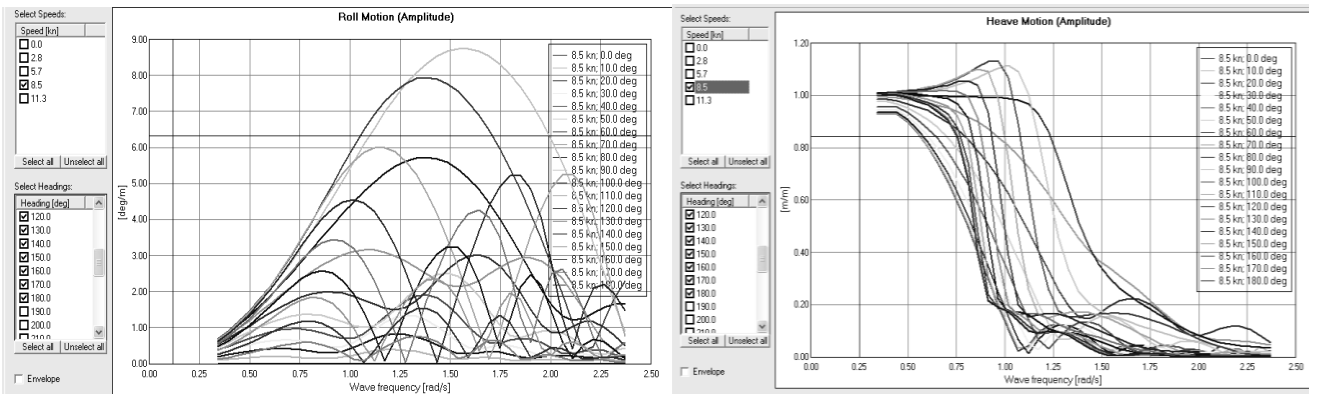
Fig. 7. Motions amplitude (roll and heave) according with wave period evolution

ROLL MOTION

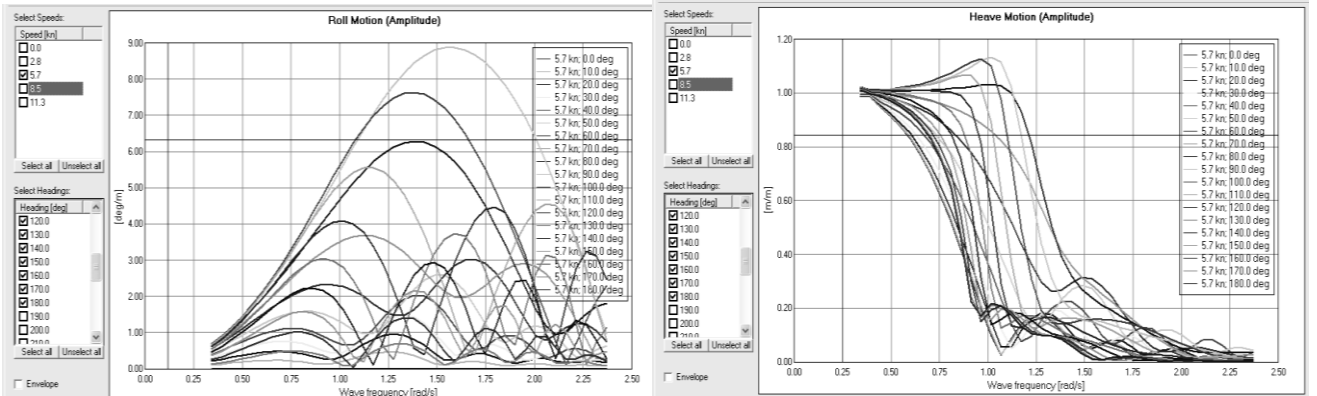
HEAVE MOTION



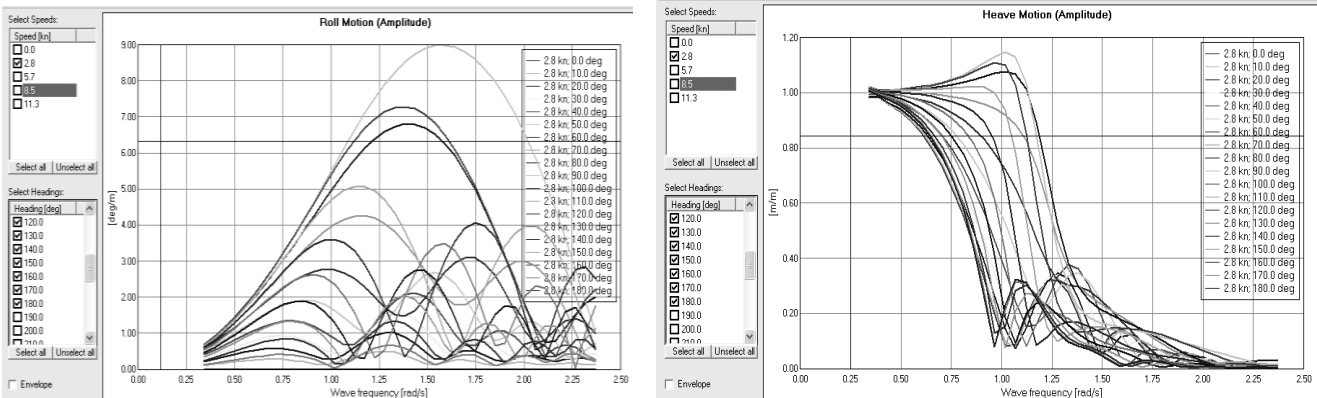
Encountering angle 0 to 180 deg; ship speed 11.3 kn



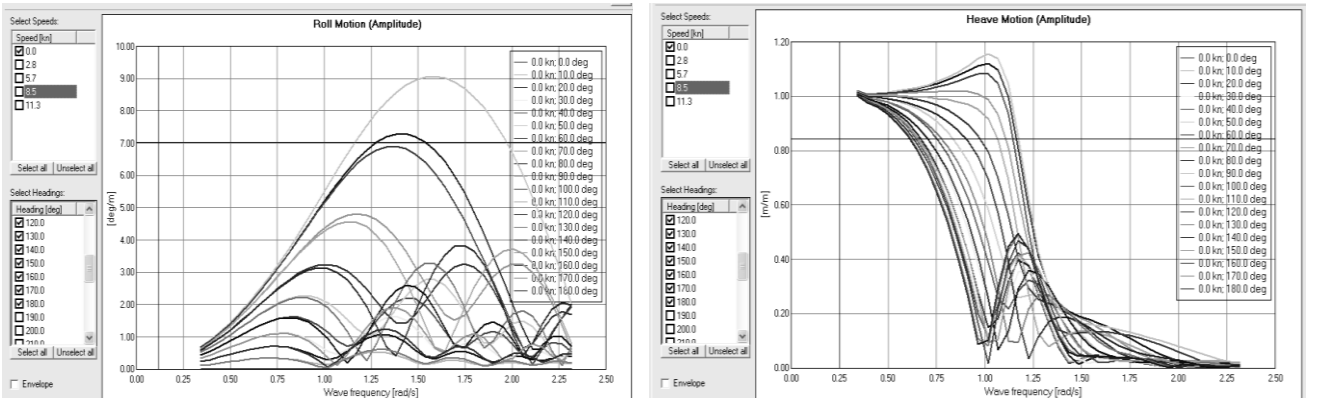
Encountering angle 0 to 180 deg; ship speed 8.5 kn



Encountering angle 0 to 180 deg; ship speed 5.7 kn



Encountering angle 0 to 180 deg; ship speed 2.8 kn

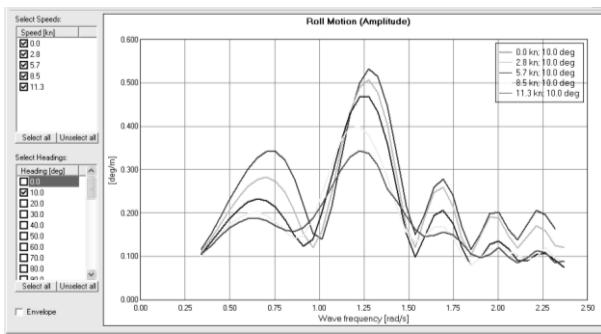


Encountering angle 0 to 180 deg; ship speed 0 kn

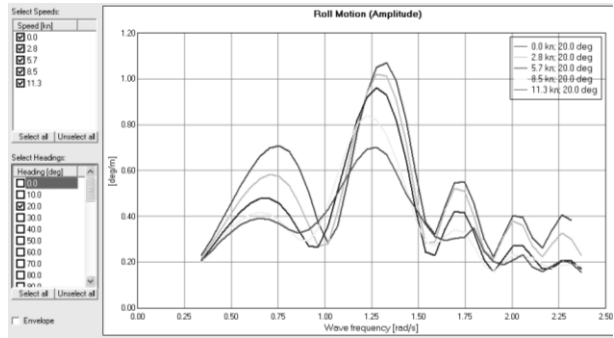
Fig. 8. Motions amplitude (roll and heave) according with wave frequency evolution

# ROLL MOTION AMPLITUDE

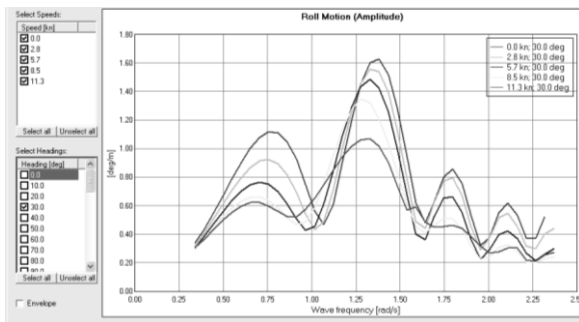
For the ship speeds: 0; 2.8; 5.7; 8.5; and 11.3 kn



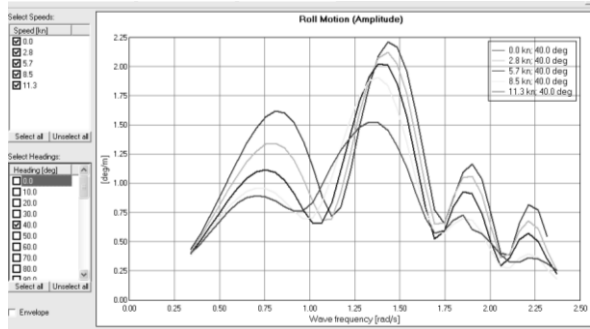
Encountering angle 10 deg;



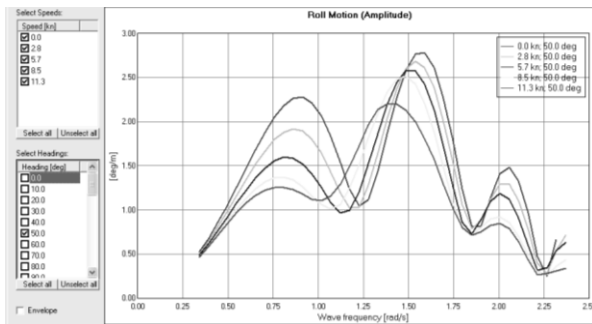
Encountering angle 20 deg;



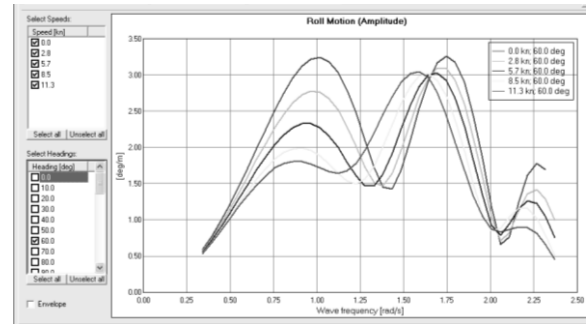
Encountering angle 30 deg;



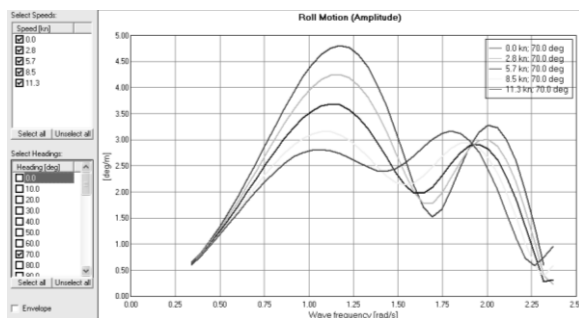
Encountering angle 40 deg;



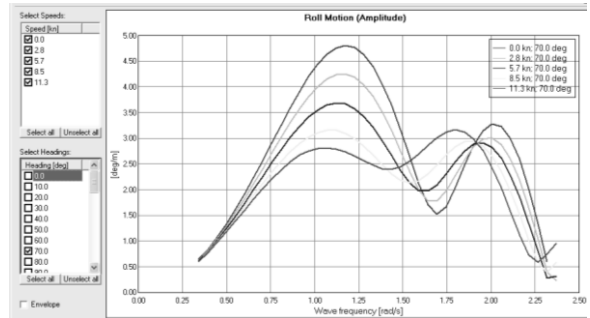
Encountering angle 50 deg;



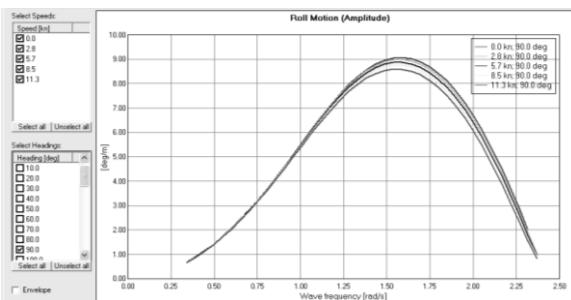
Encountering angle 60 deg;



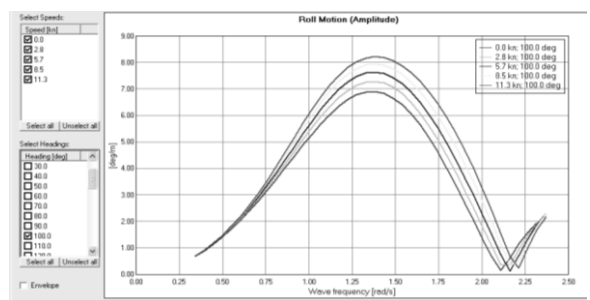
Encountering angle 70 deg;



Encountering angle 80 deg;



Encountering angle 90 deg;



Encountering angle 100 deg;



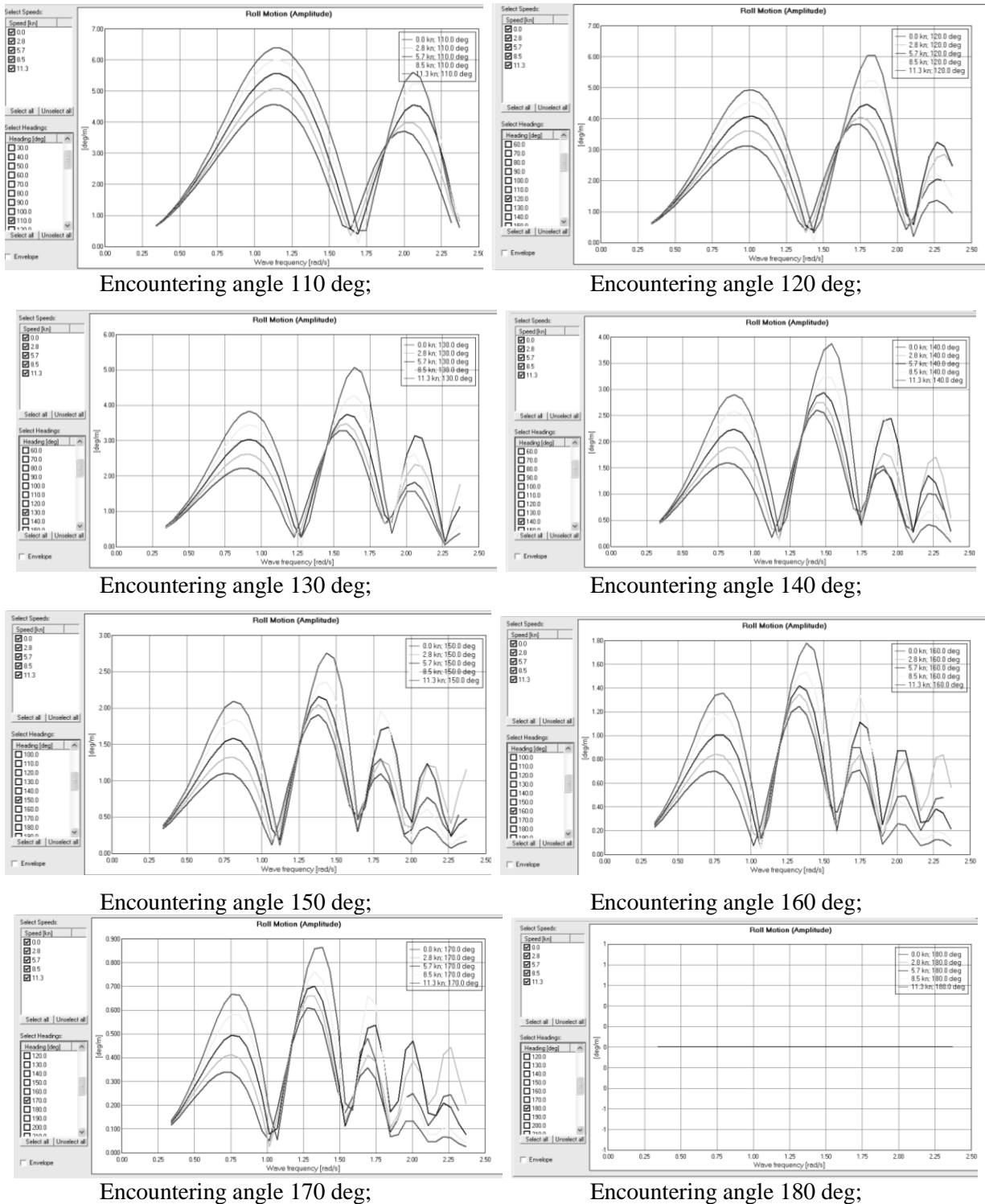


Fig. 9. Superpose representation of roll motion amplitude for the 5 speeds considered for the ship

## 5. CONCLUSIONS

Offshore supply vessels often work in difficult conditions for navigation. Not only the degree of agitation of the sea raises various and complex problems, but also the proximity of drilling platforms and other ships positioned in the immediate vicinity. It is important both collision avoidance and maintain the vessel in a controlled position relatively fixed. To achieve these objectives, the ships are equipped with

sophisticated navigation systems including dynamic positioning systems.

In recent years it has become increasingly urgent need to predict, control and correct the movements which ship can perform in real sea as rigid body with six degrees of freedom. The problem became even more important as developed functional specificity of ships. Vessels serving the offshore oil and gas industry have felt the faster and stronger this need.

OCTOPUS is a tool that meets these needs and is increasingly present on board ships serving the interest of the sailing crews.

In the case study to highlight the features and performance software OCTOPUS, considered simple roll and simple heave movement of a ship-type PSV in Mediterranean sailing conditions.

Although they have been studied as decoupled moves, so roll oscillations and vertical, in fact, mutual support not only influences but also from the other four types of movement: surge and sway as a translation movement and pitch and yaw as a rotational movements.

The value for the hydrodynamic coefficients and for the additional masses  $a_{i,j}; b_{i,j}; c_{i,j}$   $i = \overline{1,6}; j = \overline{1,6}$  was established considering these influences.

The study considered an incident wave system resulted from superposition of 15 regular-type cosine waves with significant heights between 0.96 and 23.89 m, respectively, zero crossing periods between 3.5 and 17.5 sec. Testing program was made for a number of 5 ship speed: 0; 2.8; 5.7; 8.5 and 11.3 knots. The angle of incidence of ship waves was elected from 0 to 180 deg with a step-variation of 10 deg.

Analyzing the RAO diagrams for transverse and vertical oscillation amplitude, it can be concluded that:

-ship behavior is identical, in terms of range of motion (roll and heave) for the wave incident angle ranges between 0 and 180 degrees and 180 and 360;

-for incident waves of 0, 180 and 360 degrees, rolling ship is practically non-existent (or negligible);

-incident wave system contained in the ranges 30-50 degrees respective 120-140 degrees, rolling ship is most pronounced;

-even the worst system for incident waves, the ship is not in danger from the point of view of the functioning and vitality;

-ship speed influences the amplitude of the motions directly proportional, without the speed of 11.3 knots represent a hazard to navigation.

In this context, this paper contributes, in part, to solve problems related to the study of ship behavior in real sea, connection purpose is the highlighting the represented by numerical simulation performance.

Finally, the results provided by the program illustrate, in advance, the ship behaviour, as free rigid body in the real sea. OCTOPUS contains several utility programs exclusively naval, conducted by AMARCON (Advanced Maritime Consulting) in Netherlands. Includes routines for specific areas of interest, allowing the study of the behaviour witnessed ship on the waves.

Although the paper is not possible to see, the most important feature offered by OCTOPUS for navigation officers, is that allows tracking in real-time amplitudes,

velocities and accelerations vessel movements which run on the waves. All diagrams drawn from the analysis are active, have a dynamic behavior, are mobile and offer complex and immediate information for any vessel positions.

These results are accurate and provided a correct results with the condition of an appropriate simulations of the navigation environment (are preferred real wave spectra and not the theoretical ones). It is also important that the program data be properly loaded ship requirements to which it is subject (cargoplane, weight distribution on board, chart requests hydrostatic and hydrodynamic). Any error in the input data leads obviously to the wrong exit, untrue.

OCTOPUS is a navigational instrument still new, but it has facilities that require increasingly more. Increasingly ships, especially oil and gas offshore industry, choose to equip their vessels with this program with undeniable results in terms of controlling movements in real sailing ship.

Used simultaneously with dynamic positioning systems, OCTOPUS contribute significantly to maritime safety and ease of navigation officer's work. Ship operation becomes more efficient and safer.

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