CADMO 92
Computer Aided Design, Manufacture and Operation
in the Marine and Offshore Industries

Diodore : a numerical tool for frequency and time domain analysis of the behaviour of moored or towed floating structures

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ABSTRACT

The paper describes one part of the hydrodynamic software Diodore developed to help the designers of offshore floating systems at the different stages of their engineering activities. Three basic problems are treated in Diodore : diffraction/radiation with and without forward speed, spectral response analysis and tune domain simulation. A particular attention is given to the low frequency tune simulation model. After a brief description of the linear diffraction-radiation part, details are given on the 2nd-order and non-linear waves forces taken into account : low-frequency wave and wind forces, current and drag effects, hydrostatic and mooring restoring forces. The last part of the paper is devoted to validation tests and to applications for typical offshore structures.

INTRODUCTION

The use of moored floating systems is now common in offshore production particularly for deep waters, early production stages or marginal fields. The hydrodynamic performance of these systems at the different stages of their life (transportation and/or towage, installation, operational and survival conditions) can influence the design of the structures and of their mooring in a significant manner.

The hydrodynamic analysis of a floating production system is a complex problem. It is well-known that a moored or a towed structure has low natural frequencies for its horizontal motions. As the corresponding damping is low, large amplitudes of motion are observed which induce high tensions in the mooring lines. A similar phenomenum is observed for the vertical motions of structures with small waterplane area (semisubmersible, TLP in floatation). In that case the natural frequencies are given by the hydrostatic restoring forces. For ship or barge the roll/pitch/heave natural frequencies correspond to wave frequencies which induce resonances, particularly in roll. A specific problem is the springing/ringing response of a TLP appearing at the high natural frequencies of the vertical modes. For all these problems, difficulties come from random non-linear excitations and from the non-linearities of damping and the restoring forces.

An important research program in offshore hydrodynamic has been performed at I.F.P. for the last ten years. In this context Principia and I.F.P. jointly develop since 1985 the software Diodore. The main objective was to make available the research know-how in a "help to design" software for engineering projects. The paper describes mainly the low frequency time simulation model included in Diodore.

An efficient numerical tool must include the main environmental effects (wave, wind and current). The first step of the development was to perform a fast and accurate first order diffraction-radiation model including analytical and numerical methods. The forward speed effect which required much developments is included now with different levels of approximation. RAO of motion, drift forces and wave drift damping in regular and irregular waves are obtained. In a second step the 6 degrees of freedom low frequency behaviour has been solved in time domain to include the main non-linearities : mooring system, viscous and drag effects, 2nd order wave forces and wind forces, hydrostatics. Statistical analysis post-processor has been developed to predict the extreme values of the main parameters : motions, tensions, airgap. The last step include quality assurance procedure, validation tests and typical industrial applications. The software is now available to engineering companies and is used for the time being for the design of floating production systems in North Sea and West Africa.

The first part of the paper briefly describes the linear analysis. Details on the numerical methods can be found in an another paper. The main part is devoted to the time domain model which is described in details. The last part presents some recent applications for typical structures : semisubmersible, TLP, moored or towed ships and barges.

1 - LINEAR ANALYSIS

The aim of the linear analysis is, firstly, to obtain the wave frequency response of the structure and, secondly, to store the first order parameters used in the 2nd order computations in regular and irregular waves.

1.1 - First order wave forces

The first step to estimate the behaviour of floating structures is the computation of the regular wave forces. Based on the classical 3D wave linear theory the first order flow potential is solved using a boundary integral method [1]. Several panel methods have been tested : constant sink-sources distribution, sink-sources and dipoles distribution, linear sink-sources distribution. However a smaller computer time is obtained with the sink-source distribution without loss of accuracy if the drift forces are computed using a momentum formulation.

The corresponding Green's functions are computed with fast algorithms [6] taking into account finite or infinite depth, depending on the water depth / wavelength ratio. At this stage a steady forward speed or current effect can be taken into account, in an infinite depth assumption, using some different methods from the frequency of encounter approximation to the exact linear formulation of the free surface condition [2],[3]. The coupling effect with the corresponding steady potential appearing in the mean 2nd order loads are obtained from the solution of the Neumann Kelvin problem or its double hull approximation. Resolution of the linear systems can be performed either by a Gauss algorithm or by an iterative method when the number of panels increases. Standard outputs include added-mass and wave damping coefficients, exciting forces and moments evaluated by direct pressure integration and/or with Haskind identity, body motions in waves with external forces or moment constraints, pressures and velocities on the boby and in the fluid. Drift forces and wave drift damping are computed from three different formulations : pressure integration [2], near field momentum formulation [4] and application of the Lagally's theorem [5]. The first one has the lower property of convergence with the number of panels , while the last one is only valid for the computation of the horizontal components if the body cuts the free surface.

Several specificities have been developed to adapt the software to the design constraints :

• a significant reduction of the computer time is obtained taking into account the planar and circular symmetries of the hull geometry and of the fluid flow

• the coordinate system used in Diodore permits to describe the hull from the keel to the deck. The mesh used for the hydrodynamic computations is deduced from the specified displacement and from the center of gravity position after a static equilibrum study. The draft can be modified in an easy manner for computations of a new configuration. In some particular cases computations can be performed automatically for different drafts at the same time : variation of vertical drift forces for submerged bodies close to the free surface, tide and mean set-down effects on the wave frequency motion of a TLP.

• hydrodynamic multi-structures interactions can be taken into account. The structures are assumed to move independantly or can be linked by linear stiffnesses.

• analytical solutions have been developed [7] for the linear analysis of simple shaped bodies like columns and pontoons. Several different levels of approximation are proposed, including diffraction interaction effects between columns. Drift forces are deduced and used for an estimation of the low frequency behaviour.

1.2 - Linear response and hydrodynamic data base

A particular attention must be paid on the hull description with panels. The number of panels used depends on the wavelength and on the draft of the structure. However the mesh must be refined at the proximity of the mean free surface level for the smallest wave periods, and at the proximity of high variation of the hull geometry. Particularly sharp corners induce large variations of the velocity at their proximities. As an example the number of panels on the height and on the width of semisubmersible pontoon is chosen to insure a good description on the flow velocity, independly of the wavelength.

After computation of the first order wave excitation forces, wave damping and added mass, the equations of motion are solved in linear theory for each wave frequency, wave incidence and forward speed. Hydrostatic restoring forces computed from the mesh are taken into account. Linear restoring forces (mooring) and damping (linearized drag) can be added. RAO of motion, drift forces and linear wave drift damping are deduced. Pressure and velocity distributions (from diffraction and radiation potential) on the hull are stored for a following computation of the 2nd order low frequency quadratic transfer functions (QTF) and for structural computations. In the same way the first order free surface elevation can be estimated.

Analytical methods are currently used in the prelirninary design stage to optimize the hull geometry of semisubmersible and TLP from an hydrodynamic point of view. However numerical diffraction analysis must be performed to analyse the final concepts. The resulting hydrodynamic data base is the basic tool for the non-linear low frequency computations.

Post-processing of the transfer functions permits computation of the response spectra in specified wave conditions.

2 - LOW FREQUENCY ANALYSIS

Assuming that the motions and tensions are very dependant of the non-linear effects, a time domain approach has been retained to predict the extreme values with a good level of confidence. The time consuming is greater than for a frequency domain approach, but is not a handicap on a modern workstation. In the following the time simulation model is described in details.

2.1 - Wave, wind and current histories

The time history of the wave elevation is obtained from superimposing elementary Airy waves. Their amplitudes are computed from the wave spectrum. The phase shift of components are randomly distributed in $[0,2]\pi$ Frequencies vary in $[a\omega_p, b\omega_p]$ where ω_p is the peak circular frequency of the wave spectrum, a = 0.5 and b = 2.5 are currently used. $[a\omega_p, b\omega_p]$ is splitted into N_w (N_w=100 to 200) components ω_i with a constant step $\Delta\omega$. For each corresponding wave component the frequency is randomly selected in $[\omega_i, \omega_{i+1}]$ to insure a correct distribution of the low frequency components. In fact this method is equivalent to a random selection of the wave amplitude a_i associated to the frequency ω_i. The wave spectrum can be specified from the classical analytical formulation (Jonswap,Pierson) or from a discrete representation (ω_i, a_i).

The wind history is obtained in the same way as the wave history. A decomposition of 100 to 200 frequencies in $[cf_p, df_p]$ is retained. f_p is the peak spectrum of a Harris or a Kaimal spectrum (standart input). The 1-hour average velocity at the deck level must be specified. A particular attention must be paid on the choice of the cut-off frequency in order to obtain the correct distribution of energy in low or high frequency.

The current velocity is kept constant in time. However its variation in direction and magnitude with depth is taken into account by a linear interpolation of discrete specified values.

2.2 - Low frequency wave forces

Drift forces

The drift forces are preliminary computed from the first order potential and from the first order motions. Forward speed effect is taken into account. The horizontal components are obtained using the momentum formulation (near field method or Lagally's theorem). For vertical components a pressure integration formulation is required for floating structures.

Low frequency excitation

The low frequency wave forces are the second order wave forces taking place at the frequency $\omega_i - \omega_j$ in irregular waves. They are generally small compared to the first order wave forces. However they can excite natural periods of the structure if these periods are large and if the corresponding motions are lighly damped.

Preliminary computation of the second order wave forces at the difference frequencies $\omega_i - \omega_j$ (Quadratic Transfer Functions) must be performed. In theory the second order diffraction potentiel must be computed. In fact it can be shown that the low frequency component has a negligeable dependance of the second order potential. It depends mainly of the first order potential. The QTF are computed using the formulation proposed by Molin based on the Haskind theorem [9] where the contribution of the second order diffraction potentiel in the 2nd order low frequency forces is evaluated .

The time history of second-order loads is directly computed from the determination of the QTF. Since QTF are known for only a discrete number of wave frequencies, linear interpolations are performed to complete the determination of second-order loads for each discrete frequency of the wave spectrum. CPU requirements may be large because this method includes a double summation over the whole frequency domain

$$F_-^{(2)}(t) = \sum_{m=1}^{N_w} \sum_{n=1}^{N_w} a_m a_n F_-(\omega_m, \omega_n) e^{i[(\omega_m - \omega_n)t + \Psi_m - \Psi_n]}$$

However if the mean frequency of the slow horizontal motion is sufficiently low compared to the wave frequency $(\omega_m - \omega_n << \omega_m)$, the Newman's approximation can be used. The low frequency forces are approximated from the drift forces by :

$$F_-^{(2)}(\omega_m, \omega_n, \theta) = \sqrt{F_d(\omega_m, \theta) F_d(\omega_n, \theta)}\, sign(F_d(\omega_m, \theta))$$

Fd is are respectively the drift force. This approximation is not valid in short crest seas. The double summation can then be reduced to two single ones.

Care must be taken in the computation of the vertical components. Firstly only floating structures with small waterplane area have low natural frequencies. For other structures, a 3 d.o.f. model is retained. That is also the case of the T.L.P. in permanent configuration. Secondly the vertical motions, particularly heave, may have natural-frequencies not far from the wave frequencies. In this case application of Newman's approximation is questionable.

Horizontal wave drift damping

Taking into account the low frequency horizontal velocity modifies the low frequency wave forces computation compared to the values obtain with no forward speed. This modification is similar to a wave damping induced by the 2nd order wave effects. Experimental investigations results show that the wave drift damping has an important influence on the horizontal response of moored structures (15% to 60% of the total damping)

The basic idea to compute wave drift damping is to assume the horizontal velocity slow. At each time step this velocity is assumed to be constant and the corresponding 2nd order wave forces are deduced from wave diffraction theory with forward speed effect. In fact the 2nd order wave must be computed for different velocities varying around the current velocity.

At this step two possibilities are available in Diodore. A first approximation is to define the wave drift damping as a linear variation of the wave drift force with the horizontal velocity. A wave drift damping coefficient is obtained in regular wave from :

$$B_{wdd}(\omega) = \frac{\partial F_D(\omega)}{\partial V_{LF}}$$

F_D and V_{LF} are respectively the drift force and the forward speed (low frequency velocity). Using the quadratic transfer function of B_{wdd} and Newman's approximation, a low frequency wave drift damping formulation is obtained, similar to the low frequency wave forces.

In fact the wave drift damping is not a linear function of the horizontal velocity. Better solution is to compute directly the low frequency forces taking into account the influence of the instantaneous velocity when a time domain analysis is used. At each time step the low frequency velocity, including current, is computed and the instantaneous low frequency forces are deduced from the preliminary computation of the 2nd order wave forces, taking into account forward speed effect, with an interpolation procedure on the instantaneous velocity, wave frequency of encounter and heading. This method is more accurate than the usual method based on the numerical derivation of the drift forces from the instantaneous velocity.

Low frequency added mass

To reduce the computer cost induced by a convolution procedure, the added mass are assumed to be constant and equal to the value obtained for a zero wave frequency, in fact a large wave period taking into account the mean current velocity is used. A similar assumption is assumed for the first order wave damping.

2.3 - Viscous and drag forces

An interesting feature of Diodore is to compute loads due to current and motions from Morison equation taking into account the local fluid velocity on the structure. "Local" means that the drag forces are estimated on each part on the structure by a strip theory approximation. The local velocity includes the wave frequency relative velocity :

$$V(t,x,y,z) = V_c(z) - \dot{X}_{LF}(t) + V_{WF}(t,x,y,z) - \dot{X}_{WF}(t)$$

$V_c(z)$: current velocity varying with depth
$V_{WF}(t,x,y,z)$: 1st order wave frequency fluid velocity varying with depth
$\dot{X}_{LF}(t)$: low frequency structure velocity
$\dot{X}_{WF}(t)$: wave frequency structure velocity

$\dot{X}_{WF}(t)$ is computed at each time step from the first order motions RAOs.

In a correct formulation $V_{WF}(t,x,y,z)$ must be the velocity of the local wave field taking into account the first order diffraction and radiation effects. The difficulty is that the diffraction velocity varies around the hull. The resulting computer time to estimate this component of the velocity is too large for a realistic time simulation. In fact $V_{WF}(t,x,y,z)$ is approximated by the local Airy incident wave velocity.

Therefore this approach realises a coupling between low-frequency motions and wave frequency motions. Simulations of the behaviour of a TLP concept have shown the major importance of this formulation, particularly for the extreme values estimation.

However the main difficulty of this approach is the determination of the drag coefficient depending of the instantaneous Keulegan and Carpenter number K_c and of the ratio R_v between low and wave frequency velocities. A related problem is the referring frequency (low- or wave-) used to evaluate the K_c number. Considering that the vortex shedding is governed by the wave frequency motion, K_c can be estimated from linear analysis using the total relative velocity. The drag coefficients are deduced from experimental results using the maximum values of K_c and R_e [8]. An alternative consists in performing preliminary computations with an Euler or a Navier-Stokes solver in different fluid flow conditions. The resulting forces are directly included instead of Morison formulation. This approach is well adapted to structures composed of cylindrical elements because 2D flow can be assumed.

For a floating production system, a large number of risers (including tethers) can be used and may have a significant contribution to the total drag forces on the structure. In that case a similar approach is used considering a horizontal relative velocity varying along the risers because they are fixed at the bottom level. Specific drag coefficients must be used due to different K_c and R_e numbers compared to those referred to the hull parts.

2.4 - Wind forces

The wind forces are computed at each time step from the instantaneous wind velocity. A Morison formulation is used including a relative velocity formulation. The major difficulty is to obtain the drag coefficient and an estimation of the vertical position of the application point of the wind force. For ships, data can be found in the litterature. But for structures with large deck equipments wind tunnel tests are generally required. It is important to note that the wind forces generally induce a significant contribution to the low frequency motion.

2.5 - Hydrostatic restoring forces

Hydrostatic of floating structures

First order hydrostatic restoring forces deduced from the linear hydrostatic matrix are computed. Also second order hydrostatic restoring force are used and available for structure like semi-submersible.

Hydrostatic of TLP

For TLP low frequency motions appear only for the horizontal components. However the stiffness of the tethers induces a set-down effect relative to the instantaneous horizontal offset and wind induces pitch and roll inclinations. The resulting added hydrostatic forces are computed at each time step by finding the equilibrium position of the platform. The following equation is solved using an iterative procedure :

$$\sum_{j=3,5} F_j^{wind} + F_j^{drag} + F_j^{LF} + F_j^{tethers} = K_H(j,j)X_j$$

$X_j, j = 3,4,5$ are the components of the instantaneous platform position, i.e. heave, roll and pitch. $K_H(i,j)$ is the hydrostatic stiffness matrix. The computation of the external forces includes the horizontal low frequency and wave frequency components of the motions. A difficulty is the accuracy of the computation because the roll and pitch angles are very small compared to the set-down. However the corresponding tether tensions are not negligeable. The horizontal motions are modified in this procedure step because they depend on the horizontal tethers tensions.

2.6 - Mooring restoring forces

Catenary mooring lines and hawsers

The restoring forces induced by the mooring system are computed at each time step from the mooring characteristics. Dynamic behaviour of the mooring lines is neglected. A pseudo-static modelisation is used. From the instantaneous position of the top attach point, the static equilibrium position of the lines is found and the pseudo-static tension is deduced. The mooring lines are assumed to be composed of elastic catenary elements, floaters and penders. If at a given time step a tension is greater than its breaking limit then the corresponding line is automatically suppressed but the time simulation continues. There is also a possibility to break a line at a specified time in order to simulate damage conditions. The approach permits to take into account the main non-linear effects induced by the mooring system. However the damping induced by the mooring lines must be included from external dynamic computations. When the structure is connected to an another fixed or floating structure, the hawsers used are modelised in the same way. An another possibility is to compute the non-linear restoring laws from an external specific software. In that case the restoring forces are obtained from an iterative procedure using a mooring data base.

Tethers

The tethers are assumed to be rigid and the axial restoring force of a tether is assumed to be linear. The total restoring forces are computed from the instantaneous mooring attach point positions taking into account the low frequency and the wave frequency motions and from the instantaneous elongation and angular deviations from the vertical axis. The tether tensions are computed at each iteration of the procedure described in the previous section and in fine at each time step when the set-down, pitch and roll inclinations are known.

In fact a mixed mooring system, including tethers, catenary lines and/or hawsers can be modelised. This possibility is particularly useful to analyse the behaviour of structures in temporary or installation configurations.

2.7 - Low and wave frequency response

The 6 d.o.f. low frequency motions are computed applying Newton's law in time domain allowing to take into account any non-linearity. However the problem can be reduced to the low frequency horizontal motions. In fact the low-frequency vertical motions (heave, roll, pitch) are of particular importance for semi-submersibles and for TLP in installation conditions.

At each time step of the time domain simulation the computation steps are the following :

- the components of the low frequency motions are computed using a Runge-Kutta algorithm. The external forces are the low wave frequency forces, the wind forces, the tether restoring forces and the drag forces taking into account the first order relative velocity component. The wave drift damping is included in the low frequency wave forces

- the wave frequency motions are computed from the RAOs obtained in linear analysis and from the wave elevation :

$$X_{WF}(t) = \sum_{j=1}^{j=N} A_j(\omega_j) X_j^{RAO}(\omega_j) \sin(-\omega_j t + \phi_j + \psi_{X_j})$$

where ϕ_j and ψ_{X_j} are the phase of the wave component and the phase of the motion respectively. Then the horizontal components are added to the low frequency components to give the total motion

- for TLP, from the previous results, the external forces are computed again and the set-down, roll and pitch angles are calculated to obtain an equilibrium position of the platform (iterative procedure). The heave, roll and pitch wave frequency motions are taken into account.

- then the following parameters are stored for a post statistical analysis over the simulated time :

- first order incident wave elevation
- wind velocity
- mean wind, wave and current forces
- motion amplitudes (included low- and wave frequency components)
- mooring lines tensions

The time simulation duration varies from 100 to 200 times the largest natural period. However a transient part of approximatively 20 low frequency periods is removed before the statistical analysis is performed. The time step, depending of the problem, varies from 0.1 sec. to 1. sec. The statistical analysis is performed to obtain the mean, r.m.s, minimum and maximum values of each parameter. The response spectra are deduced.

2.8 - Airgap estimation

Airgap is an important parameter for the design of semisubmersible platform and TLP. So a particular procedure has been developed to compute it. Firstly RAO of the first order wave elevation is computed for each specified point during the linear analysis stage. The forward speed effect induced by the current and by the low frequency velocity is taken into account. Then, during the low frequency simulation, airgap is computed at each time step from the first order free surface elevation $\eta_M(t)$ (using RAO from linear analysis) and from the vertical motion due to the low frequency motion or set-down effect $Z_{ST}(t)$:

$$Z_M(t) = Z_{M,0} - Z_{ST}(t) - \eta_M(t)$$

$Z_{M,0}$ is the initial position of the point M over the mean water surface including the variation of the water level induced by the tide and the storm surge. This approach permits to take into account the phase shift effect between the free surface elevation and the dynamic motions of the structure. The pitch and roll motions due to the overturning moments (wind, wave and drag effects) are taken into account.

2.9 - Extreme values

The prediction of the extreme values is generally difficult in low frequency problems. The low frequency wave forces are not Gaussian and the low frequency motion equations are non-linear. These non-linearities are mainly due to the drag and to the restoring forces. Two different ways can be followed. The best approach is to perform statistics on several simulation of the same case. As the distribution of the wave components from the spectrum is arbitrary determined for the modulus and the phasis, every simulation is different. When keeping the maximun values of each simulations, one can fit a statistical law (Gumbel law, Weibull law). However the resulting computer time is too large to repeat the procedure for each case. A second approach is to fit the peak distribution on an empirical law for each case. Then the asymptotic form of the peak distribution law is used to estimate extreme values.

3 - SOFTWARE ENVIRONMENT

Diodore has been developed since 1981 by a group of scientific experts using quality assurance procedures. The software is well documented with a user manual, a theorical manual and an example manual. Diodore's architecture allows users to implement their own developments in an easy way. The software is actually running on many kinds of computer and system

Diodore includes other possibilities to solve some hydroelastic problems, acoustic radiation problems and sloshing tank problems. In January 1992 a new compagny, DIODORE Systeme, has been created to edit and market the software and to prepare its extension to fluid dynamic computations.

4 - VALIDATION TESTS AND TYPICAL APPLICATIONS

4.1 - Validation

Since 1985, validation tests have been performed for the first order analysis refering to existing analytical solution and model tests results [7]. More recently second order wave forces have been computed for international comparison tests on typical structures :

- a tension leg platform (TLP) proposed by ISSC [7]
- a deep draft floater (DDF) and a turret production ship (TPS) proposed in the FPS2000 project [11]

However a more important attention has been paid to the validation of the low frequency time domain model. The difficulty was the calibration of the statistical values of the simulation for the main floating production systems. Comparisons have been performed with model tests results for :

• a single point moored tanker (model tests performed by NSMB for a JIP) [10] : attention has been paid to wave drift damping
• the DDF and the TPS systems (FPS2000 project) : prediction of the horizontal offset and estimation of the extreme values [11]
• the concrete semisubmersible Nekton 8000 developed by Bouygues Offshore and IFP : horizontal and vertical low frequency motions, mooring lines tension, airgap estimations [12].

4.2 - Typical recent applications.

After the first step of validation and calibration, Diodore was available for engineering analysis. During 1991 and 1992, the software has been required for hydrodynamic analysis of several important engineering projects. The main are :

• a concrete TLP concept for Heidrun field (KSD) during the preliminary design stage the low frequency behaviour in permanent, temporary and installation configurations and in extreme conditions has been analyzed : offset, set-down, tether tensions, airgap, roll and pitch during installation
• towage of the Palanca barge (SNEA(P)) : added wave resistance and fis-tailing analysis under tow
• a concrete semisubmersible concept from Troll Olje field (KADOC) during the preliminary design stage : low horizontal and vertical low frequency motions, mooring lines tension
• a production barge for N'KOSSA field (SNEA(P)) : horizontal offset and and extreme mooring lines tension, design of the mooring systems.

For these projects extensive experimental tests have been performed (extinction tests in still water and in waves, long time simulation in irregular waves). The analysis of results permits to calibrate the numerical tool particularly for the prediction of damping terms in different conditions.

5 - FUTURE DEVELOPMENTS

The scientific content of Diodore is continually increasing using the results of research and development projects performed at Principia. A project (supported by CEPM/FSH) has permit to develop the wave drift damping formulation. A french JIP on low frequency damping has started in 1991 supported by the CLAROM. Diodore has been used to compute successfully wave drift damping in potential theory. Second part of this JIP is concerned with viscous damping. In the same way a Pincipia Ph.D thesis is under achievement to give significant results to be included in Diodore (Euler and Navier-Stokes solvers).

Recent numerical development [13] has shown that the frequency of encounter approximation may not be sufficient to evaluate wave drift damping. Therefore, different developments to take into account more precisely the effect of velocity have been developed. The complete resolution of the diffraction-radiation with forward speed problem, the Grekas formulation, and an original development using the Brard number $\tau = \omega V/g$ are different alternatives available in Diodore.

REFERENCES

1. Berhault C., Molin B., Bougis J. and Guevel P., "Alternative methods for the numerical analysis of the linear response of semisubmersible platforms in waves", OMAE, Houston, 1987

2. Berhault C., Coudray T. and Villeger, "A scope of different methods to compute drift forces and wave drift damping in regular waves", 7 th Workshop on Water Waves and Floating Bodies, Val de Reuil, 1992

3. Coudray T. and Le Guen J.F., "Validation of a 3D-seakeeping software", CADMO 92, Madrid, 1992

4. Molin B. and Hairault J.P., "On second order motion and vertical drift forces for 3-dimensional bodies in regular waves", Int. Workshop on Ship and Platform motions, Berkeley 1983.

5. Guevel P. and Bougis J., "Méthode tridimensionnelle de calcul de la resistance ajoutée d'un navire sur houle", ATMA, 1985

6. Bougis J. and Coudray T, "Méthodes rapides de calcul des fonctions de Green des problèmes de Neumann-Kelvin et de diffraction avec vitesse d'avance", 3ièmes Journée de I'Hydrodynamique, Grenoble, 1991

7. Berhault C. and Molin B., "Calcul des efforts du premier ordre sur les plateformes semisubmersibles : choix d'une méthode", lère Journées de l'Hl'Hydrodynamique,Nantes,1987

8. Le Marchand E., Berhault C. and Molin B. ,"Low frequency heave damping of semisubmersible platforms: Some experimental results", BOSS'88

9. Molin B. , "Quelques reflexions sur la resolution du problème de diffraction au deuxième ordre", lère journées de 1'hydrodynamique, Nantes, 1987

10. Le Buhan P. , "Etude du comportement a 1'ancrage de supports flottants" Rapport de stage I.F.P., Aout-octobre 1989

11. FPS2000 Comparative study. Workshop, Presentation of data NORWAY 1989

12. Molin B., Berhault G. and Le Marchand E. , "Comportements non-linéaires des plates-formes semisubmersibles", 2ièmes journées de 1'hydrodynamique, Nantes, 1989

13. J. Nossen, J. Grue, and E. Palm, "Wave forces on three-dimensional floating bodies with small forward speed" Journal of Fluid Mechanics, vol 227, 1991

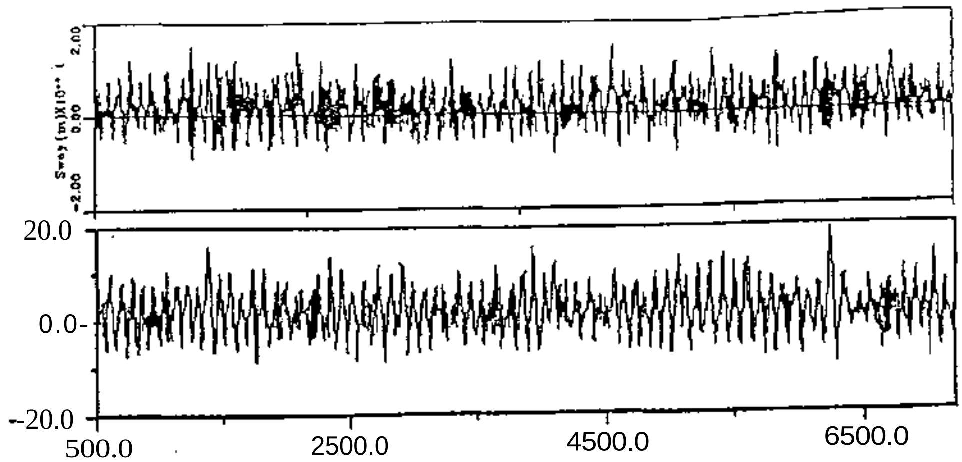

Fig. 1 : Comparison model test/simulation for sway motion
for the semisubmersible NEKTON 8000 with catenary lines
Up : Measured - Down : simulation

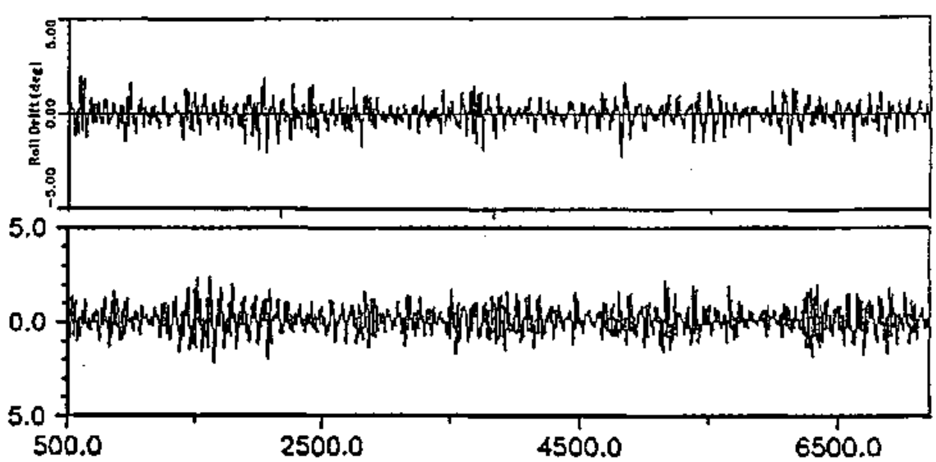

Fig. 2 : Comparison model test/simulation for roll motion
for the semisubmersible NEKTON 8000 with catenary lines
Up : Measured - Down : simulation

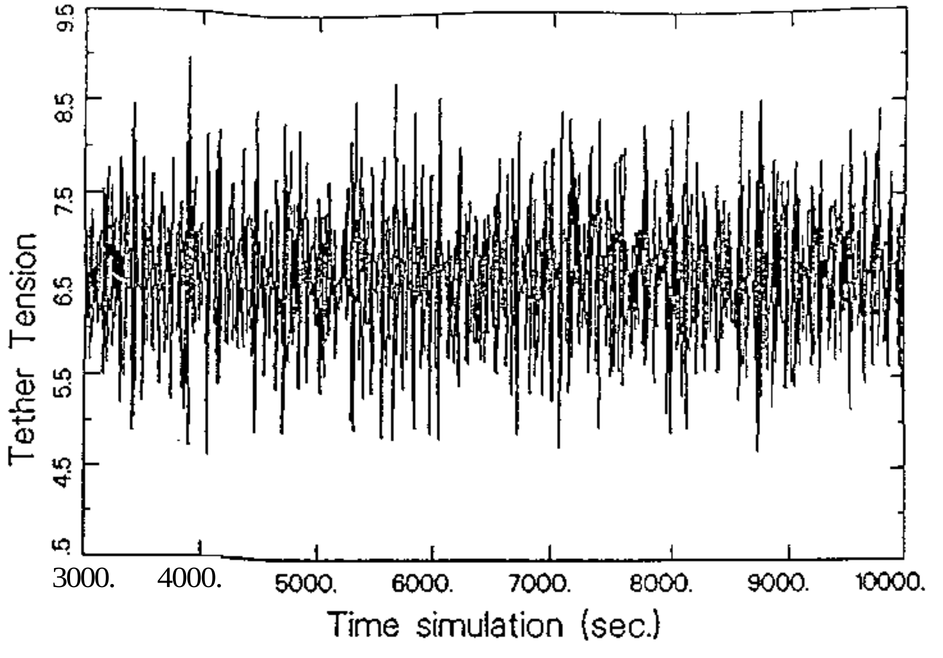

Fig- 3 : Simulation of tether tension of a T.L.P.

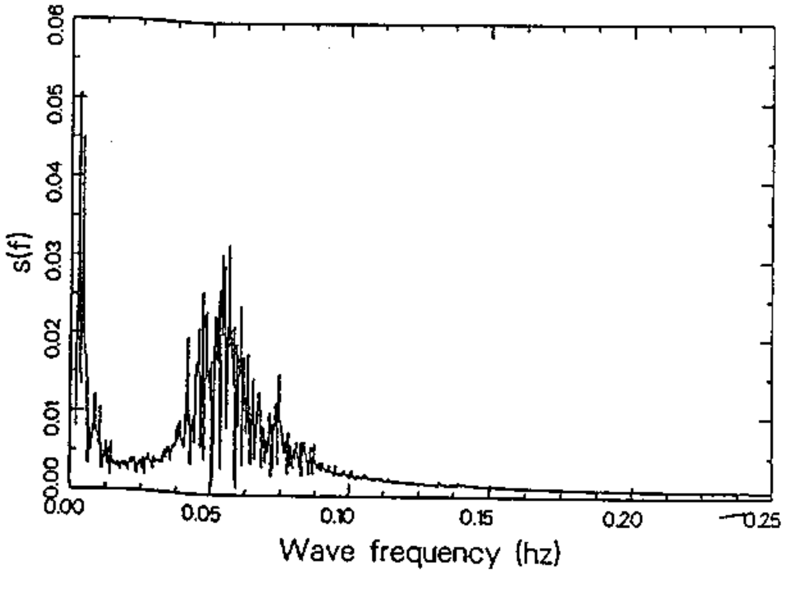

Fig. 4 : Tether tension corresponding spectrum

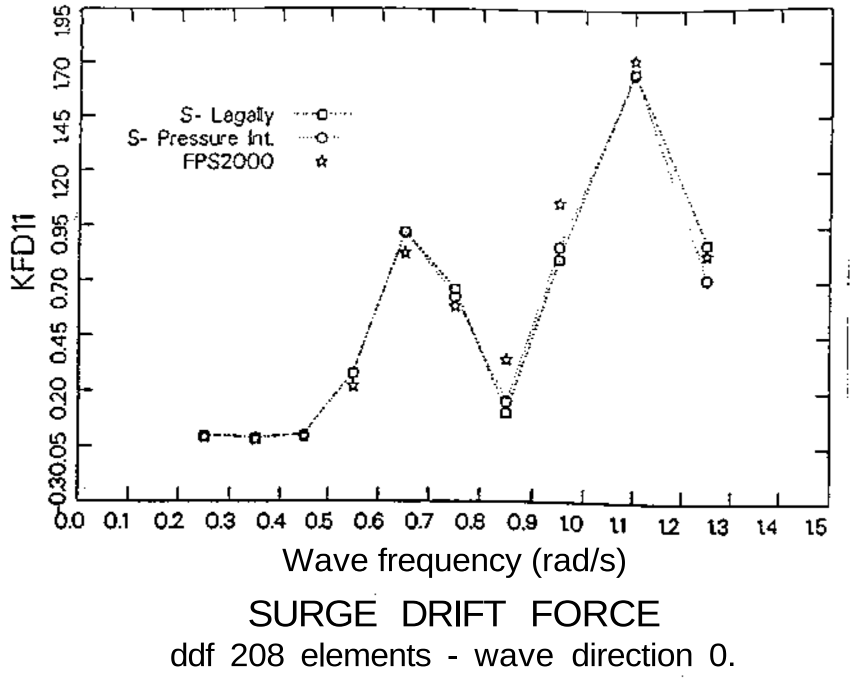

Fig. 5 : Comparison FPS2000./Diodore for surge drift force

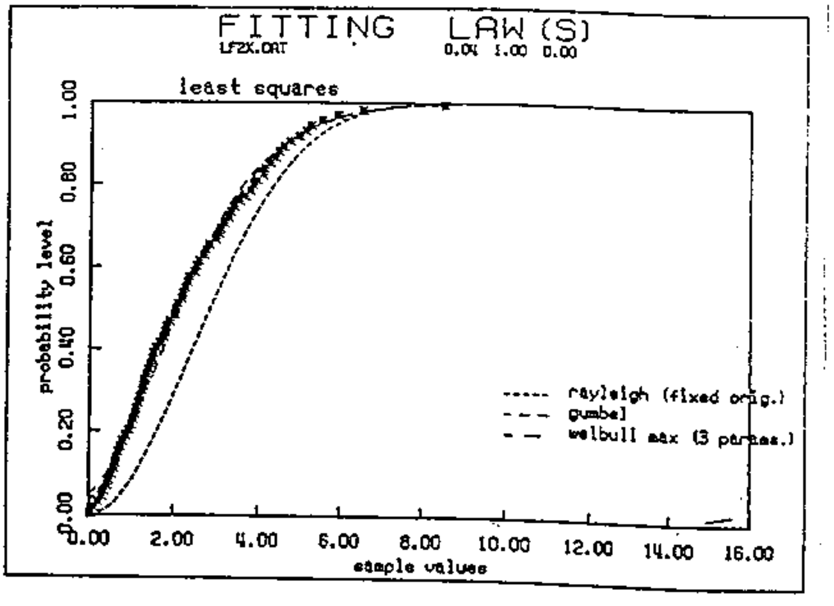

Fig. 6 : Offset of a T.L.P : peaks distribution laws

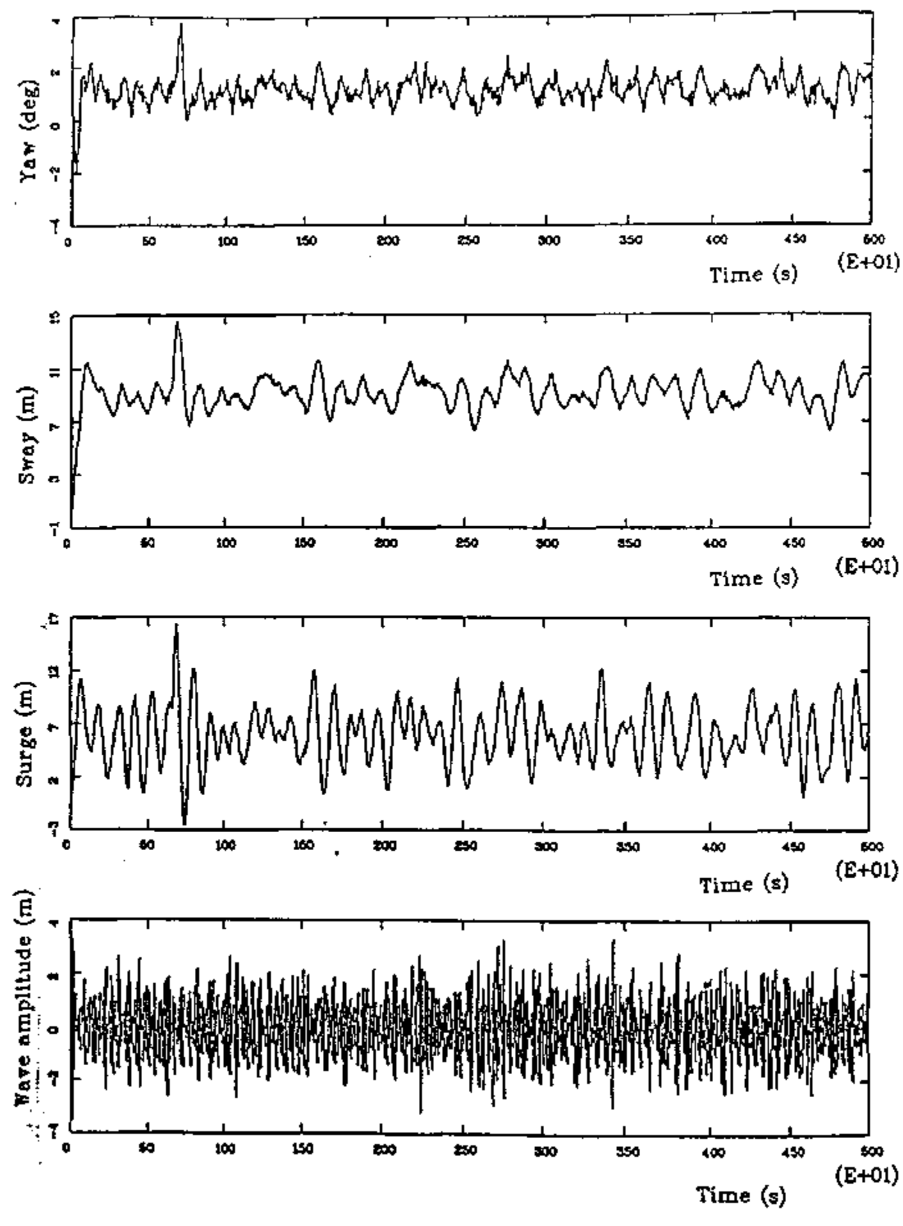

Fig. 7 : Standart outputs of low frequency time domain simulation of Diodore for an anchored barge