Model of a moored power cable at OBSEA platform

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Abstract - *New green energy sources deployed at sea in mobile platforms use power cables in order to transport generated energy at sea surface to the bottom. Theses power cables are exposed to the dynamic behaviour of the platform movements due to waves, currents and wind. OBSEA is a seafloor cabled observatory at 20 m depth in front of Vilanova, in Catalan coast. OBSEA captures data in real time like current, waves and wind among others. In this paper, a model of a moored power cable installed at OBSEA is studied. The study is focused on the trajectory, tensions and deformation or curvature of cables about 0.1 m diameter and under real conditions collected from OBSEA sensors. Simulations are done with OrcaFlex 9.3 software (license N1594). This software allows to model underwater structures and cables.*

Keywords - *Simulation, Sea Mooring, Power Cable, Data Acquisition, OBSEA*

I. INTRODUCTION

Simulation of the static and dynamic power cable behavior due to marine conditions is useful to be done before the design and deployment of the cable by a manufacturer, in order to identify critical parameters like forces, effort, elongations and curvature that cable will suffer.

Many bibliography can be found about underwater cables, moorings, buoys, and many simulations exist that study dynamic cables, some of them umbilical cables, in several types of moorings [2, 3, 5, 7]. But little information is found with respect to power cables [6]. It is not easy to get some physic characteristics of power cables like the bending stiffness, because of different layers of cables fitted inside the cable.

OBSEA is a cabled seafloor observatory located 4 km off the Vilanova i la Geltrú coast in a fishing protected area of Catalan coast. It is connected to a station on the coast by an energy and communications mixed cable. The station located on shore provides the power supply and a fiber optics communication link and at the same time carries out alarm management tasks and stores data in real time. This marine observatory is located at a depth of 20 m. There is a buoy moored with 3 chains that captures data of waves, current, pressure among others. All details of OBSEA are summarized in web site www.obsea.es.

In present paper the OBSEA's buoy is modeled. Moreover a fictitious power cabled is added to the structure, it is moored from the buoy to the seafloor. The numerical simulations of this model are carried out with the help of OrcaFlex software, version 9.3c, under a educational license (N1594) [4]. OrcaFlex is a marine dynamics program developed by Orcina for static and dynamic analysis of a wide range of offshore systems. OrcaFlex provides fast and accurate analysis of umbilical cables under wave and current loads and externally imposed motions. OrcaFlex is a fully 3D non-linear time domain finite element program capable of dealing with arbitrarily large deflections of the flexible from the initial configuration.

The goal of this paper is to show the behavior of the offshore structure under real conditions. To be precise, the study is focused on the trajectory, tensions and deformation or curvature of cable and chains.

The structure of the paper is the following: in chapter II it is explained some details of real data used in simulations. The OrcaFlex model and results are given in chapter III. Finally the conclusions and further work are given in chapter IV.

II. OBSEA DATA USED IN SIMULATIONS

One of the instruments installed at OBSEA Cabled Observatory is an AWAC (acoustic wave and current profiler) that collect time series data every hour during 8 minutes and then averaged values for sea waves (significant height, direction and period) and current (magnitude and direction) are calculated. Undersea current speed and velocity to the North and to the East (if negative values this means a velocity to the South and West respectively), are collected every meter. The direction of current is easily calculated using velocity components. To get mean values of current it is important to calculate firstly the average of velocity components and then calculate the current direction, otherwise the average using degrees/radians could be done wrongly. Temperature, sound speed, pressure, chlorophyll and turbidity is also collected.

Data of wind is used from a meteorological station located at on shore, 14 m above sea level: http://meteoclimatic.com. To be precise data from 10-05-2010 is used in present paper. The reason to consider a fixed day instead of averaged values between long periods is to be more realistic with external conditions. In that day we found the bigger waves of data collected from 24-03-2010 to 23-06-2010, which was studied in paper [1].

The significant height of wave was 2.83 m with period about 5.84 s and direction of advance of 164.5º.

The maximum wind speed was 10 m/s with direction of advance about 270º (E).

The averaged values of current during that day are shown in Fig. 1.

(a)

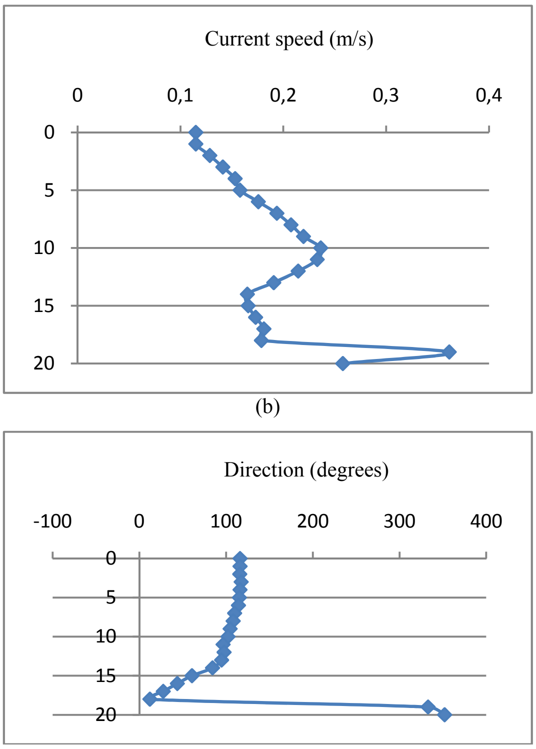

Figure 1. Current averaged data of 10-05-2010. Current speed in m/s (a) and the direction of advance in degrees (b) as a function of depth in the vertical axis.

Both graphics show a change of behavior of current from 10 m depth to the seabed. The current speed shows a local maximum of about 0.46 kn at 10 m depth and a maximum of 0.7 kn at 19 m depth, this extreme data could be due to the existence of a boundary layer on seabed or due to an error data. A direction of advance of 116º is obtained on sea surface, a decrease of only 15º is found until 10 m depth, and then a big change of direction is found until seabed.

III. ORCAFLEX SIMULATIONS AND RESULTS

The location of OBSEA buoy is: 41º10.91'N, 1º45.15'E. It is moored with 3 chains of 30 m length. Chains are moored on seabed on a circle of 20 m radius centered at buoy position and chains are equally spaced 120º. The 'first' chain is moored 10º clockwise with respect to the North.

The buoy consists of one cylinder of 4 m length and 0.8 m diameter and another small cylinder on the bottom of 0.9 m length and 0.05 m diameter. Its mass is 650 kg in air. On the bottom there is a free link to the chains with three branches of 0.65 m length, 0.03 m diameter and 130º of declination, equally distributed around.

A model with OrcaFlex environment is done. 'First' chain is located on x axis. In these local axis, North is located 10º anticlockwise from x axis (see Fig. 2). OrcaFlex inputs of directions of waves, wind and current are directions of advance. In last section we gave the real

(a) (b)

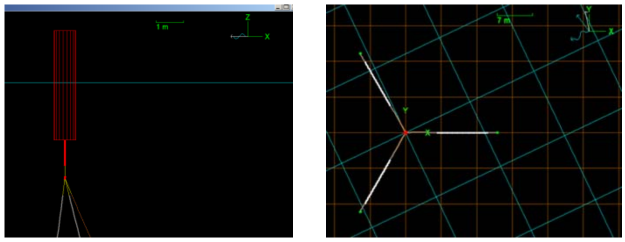

Figure 2. (a) Spar Buoy type on OrcaFlex environment and links to chains. (b) OrcaFlex plan view of buoy model after the static simulation.

Table 1. Parameters used in OrcaFlex simulations.

Parameter	Object	Value	Units
Sea density	sea	1025	kg/m^3
Kinematic viscosity	sea	1.35x10^{-6}	m^2/s
Seabed friction coefficient	cable chain	0.25 0.74	
Length	cable chain	45 30	m
Diameter	cable chain	0.1 0.026	m
Weight per meter	cable chain	22 4.3	kg/m
Bending stiffness	cable chain	7 0	kN/m^2
Axial stiffness	cable chain	700x10^3 19796	kN
Drag coefficient (x)	cable chain	1.2 1	
Drag coefficient (z)	cable chain	0.008 0.4	

directions of advance, $\alpha \in [0º,360º)$, this means a translation to a new angle 360º- α + 10º in local axis of OrcaFlex model. Using data in Section II, a periodic sea wave, a constant wind and a profile of current are imposed. To this configuration we add a fictitious power cable of 0.1 m diameter and 45 m length, moored at the steady state position [6] (35 m layback from buoy position) at 30º of x axis. The cable is attached to the link to buoy with a vertical branch of 0.65 m length, 0.12 m diameter, 60 kg/m, bending stiffness of 70x10^3 kN/m^2. Details of parameters used in OrcaFlex model are summarized in Table 1.

Dynamic simulations are done with small step size of an implicit integration method: 0.0125 s. A 3D-view of cable model after a dynamic simulation is given in Fig. 3.

Chains produce a discontinuous effect on tension results at the top end (from now called EndA), as can be observed in Fig. 4 (a). The discontinuity is also inherited by the tension of cable at EndA (see Fig. 4 (b)).

Moreover, a spectral analysis of temporal series shows a periodic behavior of tension at the top end of cable and chains. Its fundamental frequency is about 0.17 Hz; this is a fundamental period about 5.84 s (≅1/0.17), as can be seen in Fig. 5 (a). Evolution of chains tension is affected by a modulation, as can be observed in Fig. 5 (b), with a small pick at 0.04 Hz. This is called a quasi-periodic behaviour. This modulation of 25 s is too small to affect the tension behavior at cable and at buoy link (see Fig. 5 (c)).

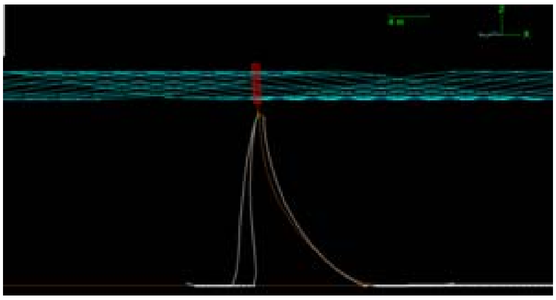

Figure 3. OrcaFlex 3D-view of buoy model with cable in a dynamic simulation.

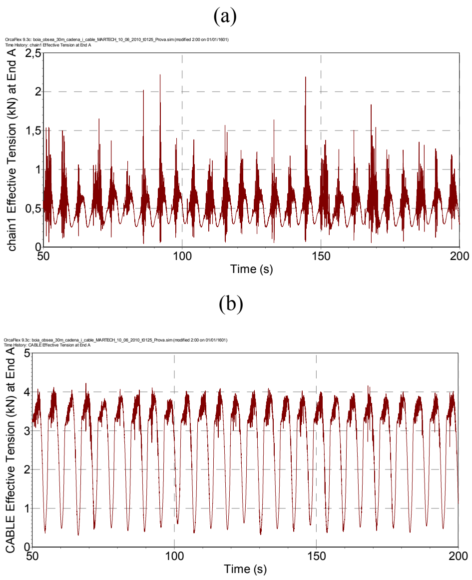

Figure 4. Temporal evolution of tension (kN) at End A of: (a) Chain on x axis. (b) Cable.

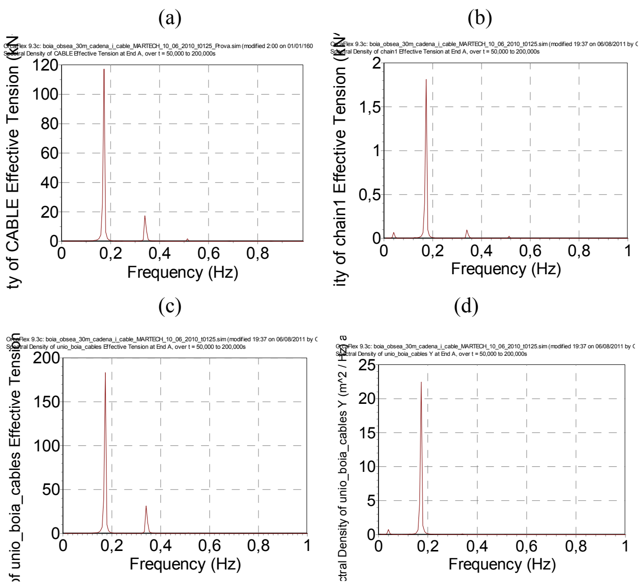

Figure 5. Spectral analysis of temporal series from 50 to 200 s. Tension (kN) of: (a) Cable at EndA. (b) Chain on x axis at EndA. (c) Buoy link. Horizontal position (m) of the link to buoy: (d) y coordinate (m).

Quasi-periodicity of chain tension is due to the movement of position of buoy, clearly manifested in component x and y (see Fig 5). Fig. 6 (a) and (b) also show a transient of about 50 s before the structure stabilizes. For this reason the spectral analysis and orbits is done from 50 s to 200 s.

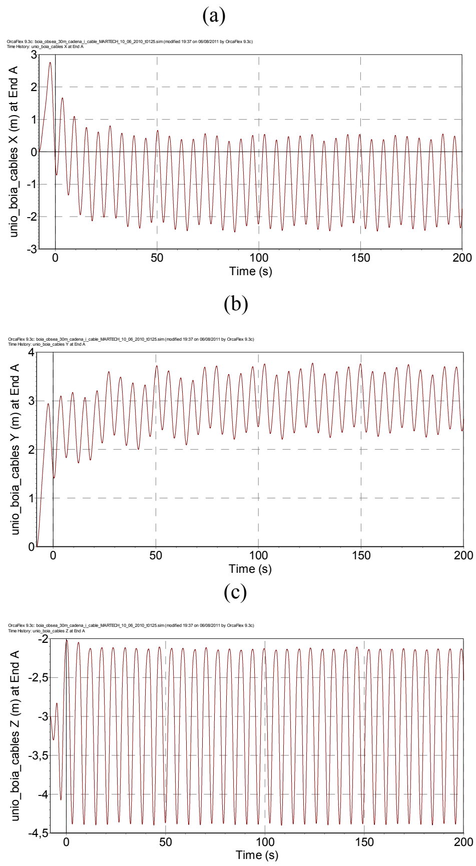

Figure 6. Temporal evolution of x, y and z, the position of the link to the buoy. Units in m.

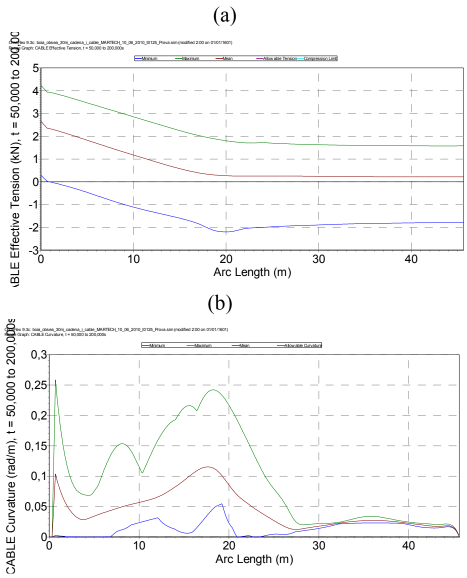

Figure 7. Range of variation of tension (kN) and curvature (rad/m) along the arc length of cable (m). Green, red and blue one mean maximum, mean and minimum values respectively. Negative tension means compression.

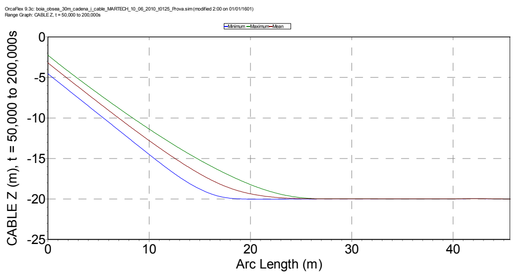

Figure 8. Range of variation of z component of cable along the arc length of cable. Green line, red and blue one mean maximum, mean and minimum values respectively. Units in m.

(a)

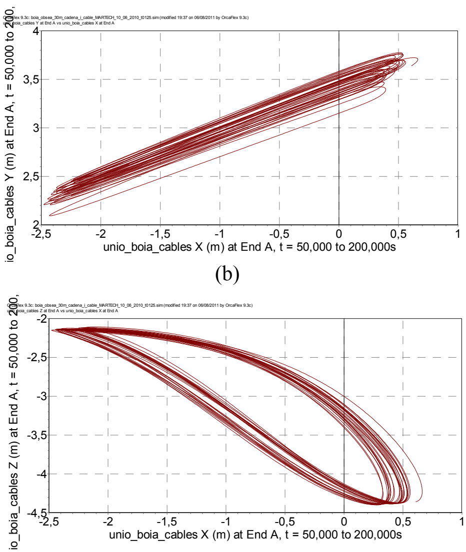

Figure 9. Orbit of the link to buoy. (a) Horizontal projection (x,y). (b) Vertical projection (x,z). Units in m.

The range of variation of tension and curvature along the arc length is shown in Fig. 7. A study of the deviation and latest figure show that two parts of cable have bigger movement: one at about 8 m of arc length and the other around 18 m, last one clearly affected by seabed contact. The seabed has a physic effect to the cable from 18 m to 26 m of its arc length can be seen in Fig. 8. The tension along the arc length of cable moves from negative values to positive ones, this means that every portion of cable moves from compression to tension with time.

Fig. 9 shows some projections of the orbit of link to buoy, for instance the horizontal movement of the link (Fig. 9 (a)). We can observe that figures show a torus as a consequence of the quasi-periodicity of orbit.

IV. CONCLUSIONS

A moored power cable in OBSEA's buoy is modeled with OrcaFlex software. Dynamic simulations are carried on under quite real conditions. A power cable is added to the existing buoy moored with three chains at 20 m depth. Periodic waves (type sinusoidal), constant wind and constant current is imposed. Data was collected from real weather conditions in OBSEA Cabled Observatory. Data of one day was chosen with the bigger sea waves.

Firstly, we have observed that chains produce a discontinuous effect on tension results; this effect is inherited by the cable tension and as a consequence by the link of chains- cable to the buoy. Secondly, the tension at the cable and at the link to buoy shows the same periodicity of sea waves. A quasi-periodic movement of position of buoy is also found, clearly manifested in horizontal components. This behavior is also manifested in chains tension. This modulation of periodic motion seems logic because of chains mooring of buoy and degrees of freedom of buoy. Finally, the study of the range of tension and curvature variation along the cable gives information about the more unstable cable segments: one at about 8 m of arc length and the other around 18 m, last one clearly affected by seabed contact. The seabed has a physic effect to the cable from 18 m to 26 m of its arc length. With this information it is easy conclude which parts of cable and structure are weaker. Ongoing simulations want to simulate with different weather conditions, and more realistic ones, different positions of cable. We will try to get the weaker parts of cable and study the movement of structure. Once a more extend study is done we will be able to know which part will need a reinforcement, for instance and simulate again. Further work will focus with the addition of a real power cable to the structure and comparison with simulations results.

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