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The Analysis Regarding the Building of a Hydraulic Power Plant on the Black Sea Shore

The present paper represents the result of a research project regarding the construction of a wave driven hydraulic plant that is going to be installed on the Black Sea shore in the area of the city of Constanta. Several phases were analyzed: numerical simulations for the micro plant – wave energy theory; finite element simulation – results and conclusions; generating the blueprint for the construction of the plant.

Keywords: *hydro-pneumatic installation, micro-power station, floor coverings, profiles, resistance module*

1. The simulation model of the wave driven hydraulic plant

The water column type hydraulic collector for the wave energy is a part of the micro electrical plant. It collects and transfer the wave energy in an air cell in which the gas is compressed and decompressed by a ram. The ram is directly driven by the waves. The compressed and decompressed air drives a turbine connected to an electrical generator. In figure 1 is illustrated a rough layout of the collector on which has been made several calculus in order to dimension it, to simulate the loadings and to check the tension and distortion or bending. The collector consists in a two openings case, one opening in the inferior part, in order to collect the water pushed by the wave pressure, and the other one in the superior part, used in the intake and exhaust of the air. The body of the collector is divided in two rooms, separated by plan of the surface of the resting water. The main process consists in the variation of water levels inside and outside the collector generating the pressure and discharge variations of the compressed and decompressed air. The objective of the research is, on one hand, to determine the burdens of the waves that actuate on the structure of the micro plant, and, on the other hand, to test the resistance of pre dimensioned structure to the actuation of the waves. The calculus was made for the specific of the Black Sea waves, including different directions of them against the collector. The parameters taken into consideration are the multiannual medium values for the representative height and period of the waves from the Romanian Black Sea shore. [1, 2, 3, 4, 5, 6, 7, 8].

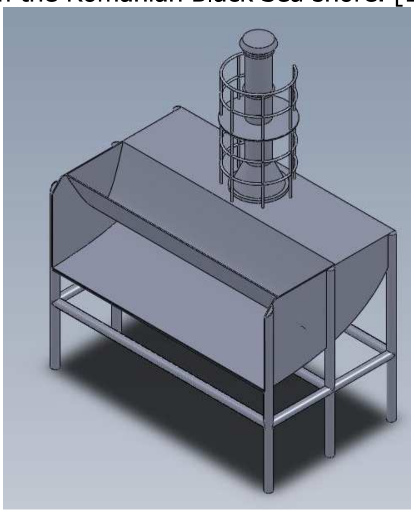

Figure 1. Hydraulic collector for wave energy

The geometrical parameters of the body of the collector were adopted in accordance with the criteria imposed by the natural characteristics of the waves from the Romanian Black Sea shore. The area of the intake opening was optimal determined using a mathematical model elaborated for the control and surveillance of the hydraulic processes inside the collector. The hydraulic process consists of an air pumping generated by the vertical movement of the water column from the collector. The vertical movement of the water column is caused by the alternative action of the external hydrostatic and hydrodynamic pressures due to the action of the waves at the intake opening of the collector. On the approach of the wave, the level of the water column rises, generating the compression and exhaust of the air from the gas cell. After the wave passes the collector, the water column level decreases producing vacuum and intake air in the gas cell. The hydraulic wave energy collector is a steel construction made of steel plate hardened with stiffening elements. The collector is placed on a mixed structure made of pipes and concrete. The elements of the structure were pre dimensioned and selected. The mechanical characteristics are detailed in table 1.

The geometrical characteristics and gauge dimensions were fixed through the projection conditions. The pressures for different loading conditions were determined according to the Goda model. The forces and moments that affect the structure were calculated using these pressures, determining the necessary weight in order to assure a minimum stability coefficient of 1.2, both in the case of dislocating and in the case of tilting. In order to determine the weight of the structure it is considered the value of the friction coefficient between the structure and the riprap at 0.6 and the value of the stability coefficient at 1.2.

Table 1 Dimensions and characteristic of the main elements of the structure

Name of material	Standard	Flow resistance $R_{eH}[MPa]$	Fracture strength $R_m[MPa]$	Geometrical characteristics	Elasticity modulus E[Mpa]	Observations
Steel plate	EN 10025-5 :2004	355	470-630	Thickness: 20mm	$2{,}1 \cdot 10^5$	High corrosion resistance
Pipe	EN 10219-1 :1997	355	490-630	$D_{int} = 139{,}7mm$ Thickness:10mm	$2{,}1 \cdot 10^5$	Unalloyed (S355j2M)
	EN 10219-1 :1977	460	550-720	$D_{int} = 139{,}7mm$ Thickness:10mm	$2{,}1 \cdot 10^5$	Alloyed (S460MLH)

Subsequent to a discretization with finite elements, using a finite element program, there were determined the tension, deformation and dislocation states. Apart from the wave loading, the structure has an additional load from the concrete on the emplacement (p=25 kN/sm). The extreme conditions for the structure – figures 2, 3, 4, 5 – are: the superior part is free; the inferior and side parts are simply supported on the concrete; the pipe stays are considered to be embedded in the concrete. For each loading situation, five different floatages were analyzed: d=1.5m, d=1.4m, d=1.3m, d=1.6m, d=1.7m

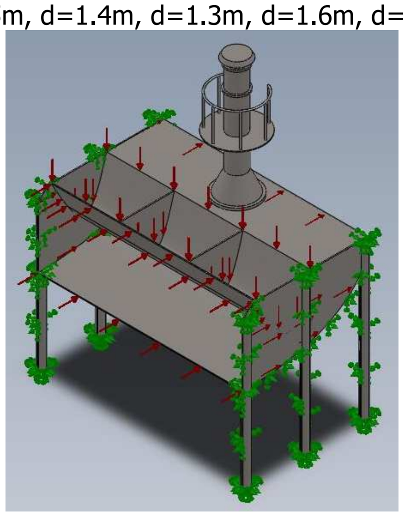

Figure 2. Extreme loading conditions for the structure

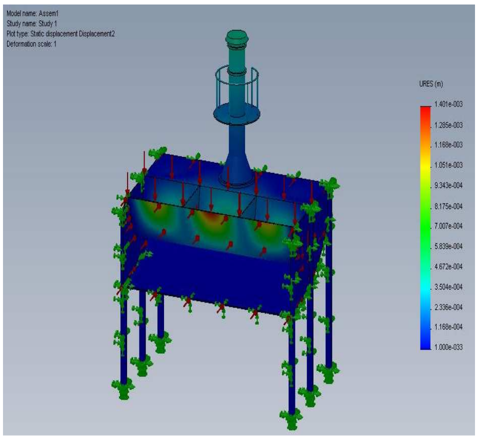

Figure 3. Dislocating state (Var 1, floating level 1.5m)

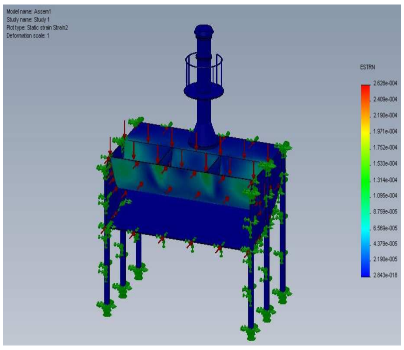

Figure 4. Deformation state (Var 1, floating level 1.5m)

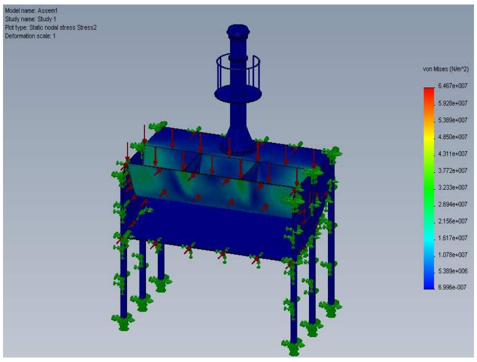

Figure 5. Tensions state (Var 1, floating level 1.5m)

The 3D model of the structure and the finite element modeling if the dynamic load of the main module of the hydraulic plant was made using SolidWorks and, respectively CosmosWorks – Figure 6.

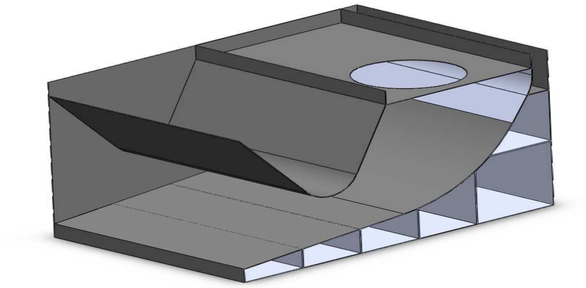

Figure 6. Section of the main module of the hydraulic plant. 3D model

2. Numerical simulation for the dynamical stress of the base module of the hydraulic plant

In order to transform the wave action into energy, a power aggregate, similar to a hydraulic plant, must be placed in the way of the waves. This system collects the waves in an artificial chamber, partially submerged, having an opening above the sea level. The opening leads to an air driven turbine. The top of the wave enters the chamber, raises rapidly the water level pushing the air above through the opening and spinning the turbine blades. In the paper are detailed the numerical results for the dynamic stress of the structure of the hydraulic plant, taking into consideration the wave action against it, analyzing in particular the structure response to the stress [9]. The numerical results are generated using finite element software. The purpose of the work is to study the response of some main components of a wave driven hydraulic plant in general, and, the study of the response of the structure of the plant to dynamical stresses [11, 12].

We are analyzing the response of the structure of the micro plant to the dynamical stress, the impact of the waves – image 7. For the numerical simulation, the following hypotheses were taken into account: the force of the waves has a bigger value than the one of the current; the variation of the pressure with the depth will not be applied; there will be used only the dynamical pressures for which distribution functions were created in CosmosWorks. The 3D domain presented before was split in volume elements in order to do the calculus of the tensions and dislocations of the structure. The meshed domain is represented in figure 8.

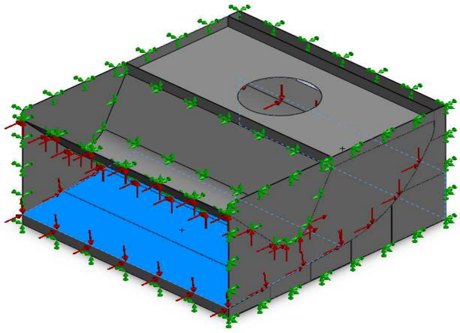

Figure 7. The model for the dynamical load of the base module of the hydraulic plant

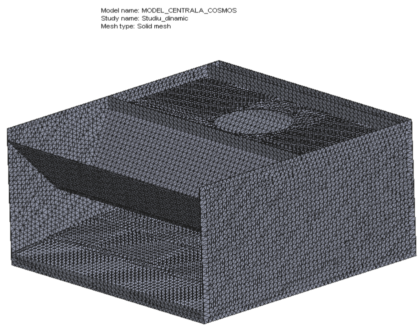

Figure 8. 3D Mesh for the base module of the hydraulic plant

The domain from figure 8 has the following characteristics: maximum size of one element: 100 mm; tolerance: 5 mm; total number of joints: 196579; total number of elements: 99742. The pressures were applied on the domain in dynamical behavior according to the principle presented in figure 9.

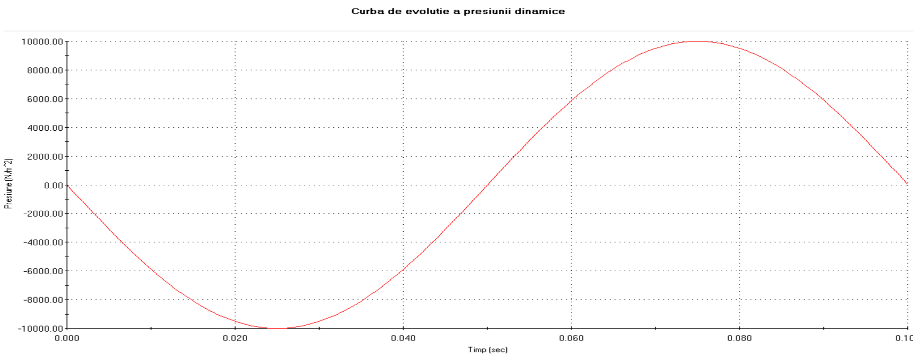

Figure 9. The principle of pressure variation against time

The maximum pressure applied is of 10000 N/m^2 and the time of the application of this pressure is of one second. It is to be mentioned that we oversized the efforts applied on the structure in order to analyze the maximum overload. The efforts were oversized with 20% - 50%. The material used in the simulation is type A steel, Romanian State Standard 8324-80, and the thickness of the plate is of 10 mm.

For the study a dynamical stress was analyzed, considering a simulation with a total duration of one second, split in 0.1 seconds steps. The material used in the simulation is type A steel, Romanian State Standard 8324-80. The results of the simulation are presented in the next 2 figures.

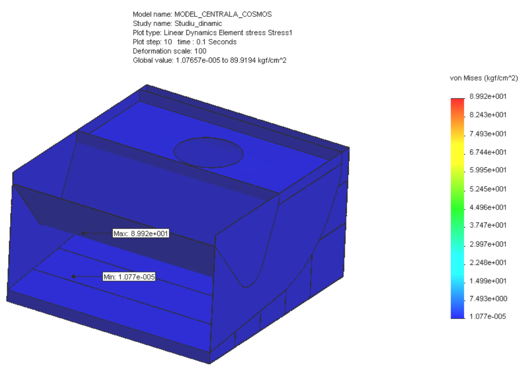

Figure 10. Tension plot. Time step 0.1 seconds

In order to observe the response of the structure, we displayed the representation of the tension contours in the material, as well as the dislocations for the intermediary steps and for minimum and maximum time steps, when the pressure values are minimal, respectively maximal. The dislocations and the maximum tensions are in Table 2.

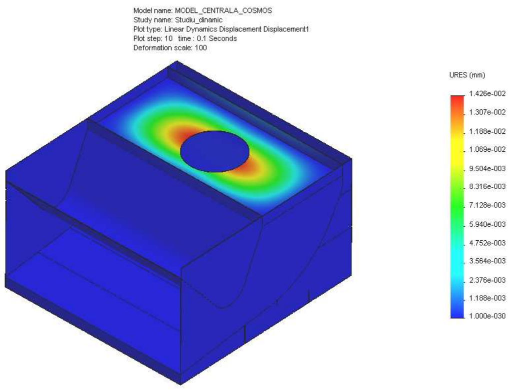

Figure 11. Dislocation plot. Time step 0.1 seconds

Table 2 – Minimal – maximal values for tensions and dislocations

Time step [seconds]	Tension [kgf/cm^2]		Dislocation [mm]	
	min	max	min	max
0,1	1,07e-05	8,99e+01	0,000	1,426e-02
0,3	1,07e-05	1,960e+03	0,000	3,107e-01
0,5	2,29e-04	1,913+03	0,000	3,033e-01
0,8	2,316e-04	1,934e+03	0,000	3,067e-01
1,0	4,472e-06	3,735e+01	0,000	5,922e-003

3. The works needed for the structure set of the power plant

In order to build the hydraulic plant in the Tomis port area, the following works will be made: the realization of a dale (base) of steel concrete class C20/25 with the dimensions of approximate 6.30 m * 6.70 m having the resistance structure of the plant embedded in it; the construction of a steel plate casing under the wave collector, stiffened accordingly in order to be filled with ballast concrete class C10/15; the construction of a handling system of the above kit, properly dimensioned in order to assure the loading, storage and assemblage; the construction of a U-type steel concrete precast, concrete class C20/25, with the section of 0.5 – 1.0 m and the inferior sides having the dimensions of the base +3…5 cm. This precast has as the main purpose the protection of the base of the structure against the waves. The following hypotheses were considered: the chosen embed method (the structure will be subsequently cast in concrete);the oversized loadings were evaluated as value in order for the results to be plausible; the value overtaking in the theoretically determined maximum points will not influence the practical behavior, the experimental determinations having to confirm the response of the structure to real time stresses [13]. The sea bed from the building area presents specific maritime deposits, represented by Holocene age sands, conchiferous sands and sands resulted from water erosion, placed on a calcareous base [10, 14].

4. Conclusion

The paper aims to check the installation system of the hydraulic plant based on innovative elements in order to exploit the Black Sea's wave energy as well as the promotion of the technological transfer in the energy conversion. The technological transfer assures the energy conversion from renewable sources, in quality and safety conditions, and, the creation of clean products and technologies in the conversion of wave energy to electrical energy. Taking into account the technical and scientific level of the Romanian School of hydro technical constructions and applied hydrotechnics, and, having the Black Sea as a base of research, the study goal is to install wave energy collectors. The application of the results of the research and the adjustment of the building and installing technologies will lead to economical effects by a subsequent production of a hydraulic power plant.

References

[1] *****Institutul National de Cercetare-Dezvoltare pentru Inginerie Electrica INCDIE ICPE-CA, *„Centrala electrica hidropneumatica actionata de valuri*" CEHPV, Contract nr: 21-001/2007.

[2] Truşcă C.V., *Cercetări şi contribuţii privind dinamica fenomenelor asociate valurilor din apropierea ţărmului, Teză de doctorat,* Universitatea "Dunărea de Jos", Galaţi, 2005.

[3] Bondar C., *Secular evolution of some components of the hydrological regime and of the Black Sea*, *Preoceedings of the world II,* CZM Center Publication, 1993.

[4] Soare S. *Procese hidrodinamice*, Editura Didactică şi Pedagogică, Bucureşti, 1999.

[5] Demirbilek Z., Panchang V., CGWAVE: *A coastal surface water wave model of the mild slope equation*, Technical Report CHL-98-26, U.S. Army Engineer Research and Development Center, Vicksburg, MS, 1998.

[6] Matulea I, Slămnoiu G. ş.a., *Modele spectrale şi probabilistice în tehnologia marină*, Ed. Fund. Univ. "Dunărea de Jos" Galaţi, 2007.

[7] Miles J.W., *On the generation of surface waves by shear flows*, J. Fluid Mech., 3, 185-204, 1957.

[8] Nwogu O. G., Demirbilek Z., BOUSS-2D: *A Boussinesq wave model for coastal regions and harbors*, ERDC/CHL TR-01-25, U.S. Army Engineer Research and Development Center, Vicksburg, MS, 2001.
[9] Hothuijsen L.H., De Boer S., *Wave Forecasting for Moving and Stationary Targets, Computer Modelling in Ocean Engineering*, B.Y Schrefler and O.C Zienkiewics, Balkema, Rotterdam, The Netherlands, 1998, p. 231-234
[10] Komar P.D., *Beach processes and sedimentation,* Library of Congress Cataloging in Publication Data, Printice Hall Inc, New Jersey, 1998, p.545
[11] Tolman H.L.*, User manual and system documentation of WAVE WATCH III version 2.22,* Tech. Note, NOAA/NWS/NCEP/OMB, 2002, p.133
[12] Van Ded Meer J.W., D'Agremond and Juhl, J., *Probabilistic Calculation of Wave Forces on Vertical Structures,* Coastal Engineering, 1994, p.1754
[13] GodaT., *Random Seas and Design of Maritime Structures,* World Scientific Publishing Co.Pte Ltd, 2000, p. 443
[14] * * * *Rules for Classification of Steel Ships*, Bureau VERITAS, chapter 4, 2009, cod nr. 467 B1DT R 04 E

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