USE OF CFD/CAE IN ECONOMICAL OFFSHORE PROJECTS

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Abstract: In this article are proposed some new solutions for economical study of offshore projects/construction using CFD/CAE software. The considered reasons for the solutions were to exactly satisfy the boundary conditions and are compared to those found in the literature. Also, a complex comparative study for modern and economical solutions is presented.

Keywords: economical study ,CFD, offshore projects.

Introduction

The planet's population is experiencing rapid improvements of living standards with concomitant increase of energy consumption. If we want more energy from conventional oil reserves or from unconventional reserves as wind power and wave energy , we have to make investments in renewable sources of offshore energy. Marine engineers will find different solutions regarding structure stiffness, elasticity, capability to withstand forces of nature but they will never asses the cost of the offshore project. This paper is intended to compare with CFD software different models in order to determine the smallest cost of construction and installation for offshore jacket structures. CFD/CAE software used into all calculations is Ansys Fluent and Solidworks, and the collected results are plotted and compared with Microsoft Office Excel.

- **New solutions for study of offshore projects**

The solution is based on a coupled software analysis using Ansys Fluent and Solidworks. A CFD-computational fluid dinamics software, Ansys Fluent, is designed to evaluate forces and fluid interaction based on Navier-Stokes equations presented below:

$$F_x - \frac{1}{\rho}\frac{\partial p}{\partial x} + \upsilon\left(\frac{\partial^2 v_x}{\partial x^2} + \frac{\partial^2 v_x}{\partial y^2} + \frac{\partial^2 v_x}{\partial z^2}\right) = \frac{\partial v_x}{\partial t} + \frac{\partial v_x}{\partial x}v_x + \frac{\partial v_x}{\partial y}v_y + \frac{\partial v_x}{\partial z}v_z,$$

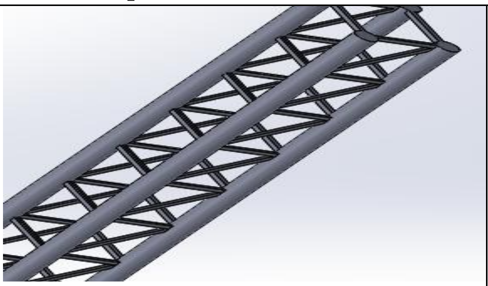
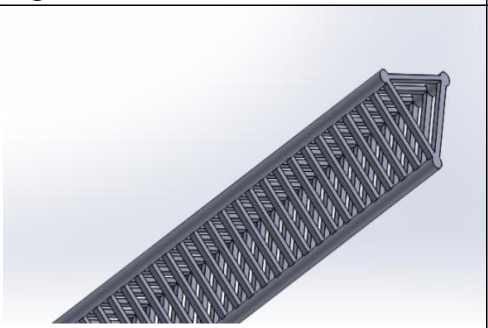
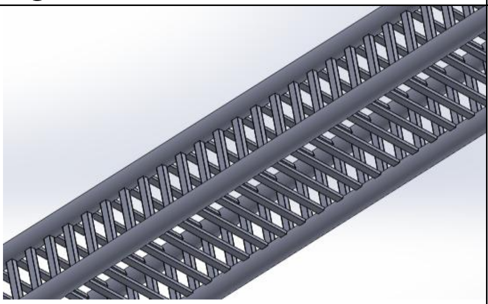
$$F_y - \frac{1}{\rho}\frac{\partial p}{\partial y} + \upsilon\left(\frac{\partial^2 v_y}{\partial x^2} + \frac{\partial^2 v_y}{\partial y^2} + \frac{\partial^2 v_y}{\partial z^2}\right) = \frac{\partial v_y}{\partial t} + \frac{\partial v_y}{\partial x}v_x + \frac{\partial v_y}{\partial y}v_y + \frac{\partial v_y}{\partial z}v_z$$ and

$$F_z - \frac{1}{\rho}\frac{\partial p}{\partial z} + \upsilon\left(\frac{\partial^2 v_z}{\partial x^2} + \frac{\partial^2 v_z}{\partial y^2} + \frac{\partial^2 v_z}{\partial z^2}\right) = \frac{\partial v_z}{\partial t} + \frac{\partial v_z}{\partial x}v_x + \frac{\partial v_z}{\partial y}v_y + \frac{\partial v_z}{\partial z}v_z.$$

where: v-speed field, p-pressure field and F_x, F_y, F_z –external force components.

This system has 6 unknown values and only 3 equations and we need more additional equations in order to solve the system. Flow modeling needs supplementary conditions to obtain the values of speed and pressure. According to the criterion we can use different turbulent models: Spalart Alarmas, RANS(Reynolds Averaging Navier-Stokes), SKE(Standard k-epsilon), k-omega, DNS-direct numeric simulation and Large Eddy Simulation (LES). We will use in our fluid simulation the SKE model. Using the CFD software we can evaluate the force acting on jacket structures and the CAE software like Solidworks can evaluate component mass and so the expected cost of construction and installation.

The CFD evaluation must be adequate to environmental conditions from the installation site, in this paper we will use data from Black Sea environmental conditions and dimensions from Gloria platform: water depth 90 m, maximum wave amplitude 12 m, wave period 10 s, maximum wind speed 164 km/h, maximum force acting on the jacket structure 2300 tones, structure length 121,9 m. The configuration and the cost analysis will be done on different models presented the table below:

 Fig.1.Model Solidworks No.1.	Model Solidworks No.1. details: Construction material: Alloy Steel Mass:240.172 kg Volume:31.19 m^3 Density:7700 kg/m^3 Weight:2353kN ECP:4.80 mil$
 Fig.2.Model Solidworks No.2.	Construction material: Alloy Steel Mass:252.22 kg Volume:32.72 m^3 Density:7700 kg/m^3 Weight:2471kN ECP:5.04 mil$
 Fig.3.Model Solidworks No.3.	Construction material: Alloy Steel Mass:288.37 kg Volume:37.40 m^3 Density:7700 kg/m^3 Weight:2826kN ECP:5.76 mil$

Ansys Fluent software allows analyzing the fluid flow around different shapes and bodies and it is an important tool in reducing experimental costs and it can accurate determine forces acting on each offshore studied model. Pressures determined with Ansys Fluent will be used in SimulationXpress Study to determine material stress and total forces acting on each case.

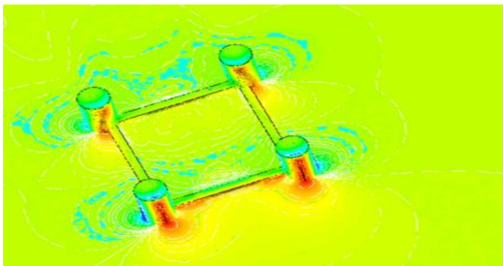


Fig.5. Pressures in Ansys Fluent

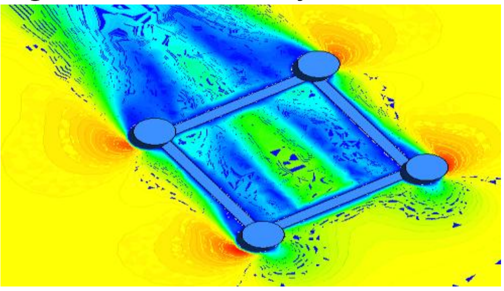


Fig.6. Speeds in Ansys Fluent

All pressures and values from Ansys will be used on Solidworks Simulation and this software can determine the capable force of the studied model. The model is no subjected to known forces and pressures and it will calculate in each poin of the structure the displacements and the stress.

In fig no.7. is shown the model based on two different software combined with the main purpose to make easier to analyze the structure dimensions. In fig.7. is presented the load scheme according to Black Sea environmental conditions: H_{water}=90 m, H_{wave}=12m, T_{wave}=10 sec, v_{curent}=2 m/s, $v_{max\ vânt}$= 44,72 m/s.

The combine scheme of structure evaluation will determine in each case the ECP(estimated cost of production and installation) based on the steel mass used to build the model in a real shipyard. So each model will be resized by a scale near to 1 in order to verify if the project is well dimensioned and we will choose the most economic project.

Results from each resized model, where k is defined as coefficient of geometrical resizing are plotted below for each studied case. The mass of the modified project is plotted and discarding any other operation related to cost we calculated the estimated cost of the structure using a material cost of 20000$/ton. Used models from fig.1,2 and 3 were resized using the k coefficient shown on the horizontal axis in figures:10,11 and 12.

We defined in SimulationXpress Study all fixed points and the forces as follows: green for fixed points, red for Ansys Fluent forces, purple for structure weight. All results for all different models used in this paper were encouraging because the displacement was not higher than 150 mm in each case according to ABS rules according the static strength calculus.

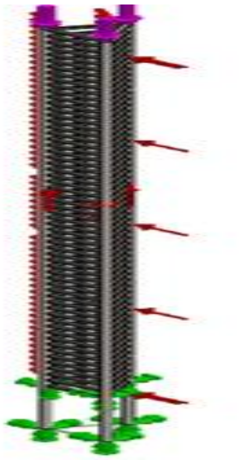


Fig.7. Mechanical loads simulated in Solidworks

- **Solutions discussion using CFD/CAE software**

Forces acting on structures are different in each case and are increasing as coefficient k increase, FoS-Factor of Safety is not constant and it is established to value of 1.25, the mass, the external acting force and the external capable force is expressed in each graphic from figures 10,11 and 12. All of runs regarding the FoS for each model determined the capable exterior force for each model according to the resizing coefficient, k, and all results were plotted in figures 10,11 and 12. FoS monitoring is possible in Solidworks software with SimulationXpress Study. The results, shown in fig 8 and 9, are according to the technical literature from ABS rules and the FoS value used can be modified if necessary in a future work to determine a stronger structure.

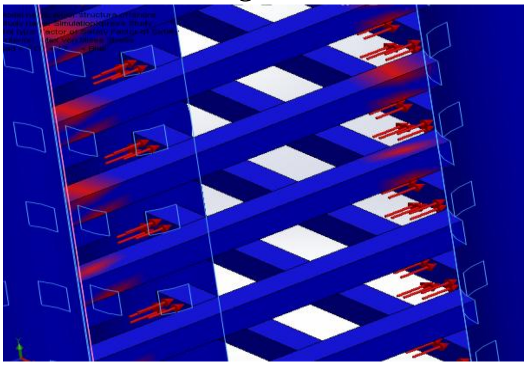


Fig.8. FoS determination with Solidworks

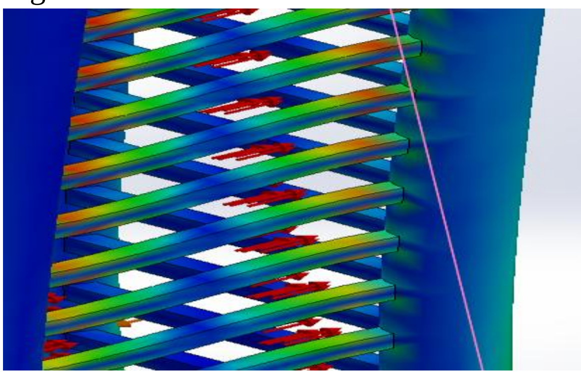


Fig.9. Stress values in Solidworks

This solution of comparing offshore projects using cost markers related to structure characteristics is presented in graphics 10, 11 and 12. Model no.1 is capable to withstand force simulated with Ansys software at k=0.92 with a FoS=1.25. In this particular situation we have a different production cost smaller than the original project.

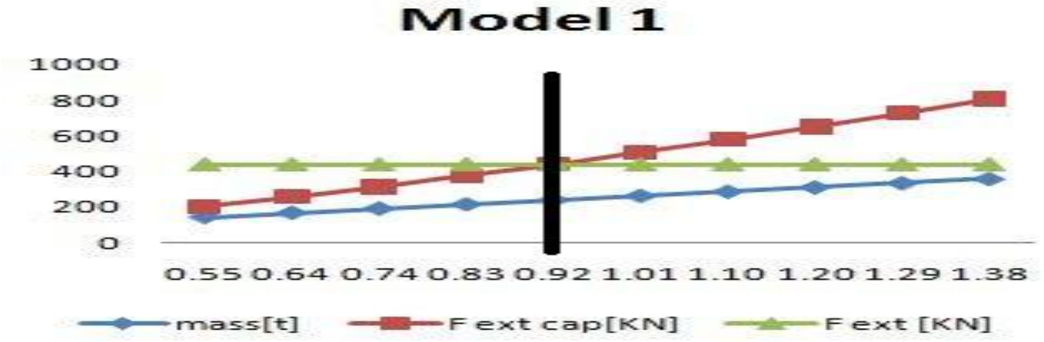


Fig.10. Model 1 mass and forces

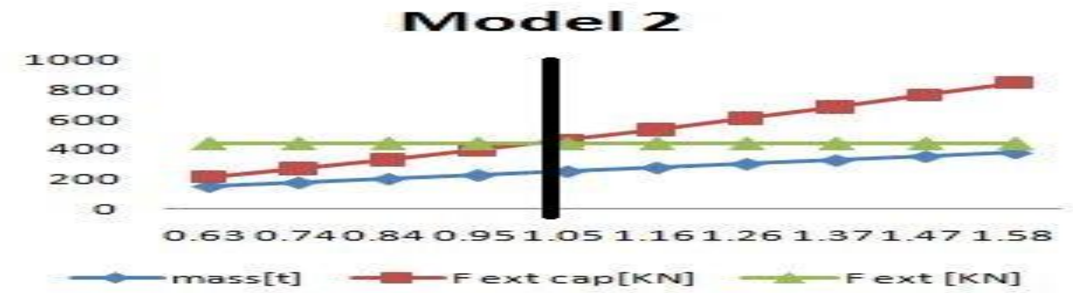


Fig.11. Model 2 mass and forces

Model no.2, shown in fig.2. is responding different to this complex analysis Ansys-Solidworks and for FoS=1.25 we need a k=1.05 to reach the point of intersection between the external capable force and the acting force on the structure.

Model no.3, shown in fig.3. is responding different to this complex analysis Ansys-Solidworks and for FoS=1.25 we need a k=0.95 to reach the point of intersection between the external capable force and the acting force on the structure.

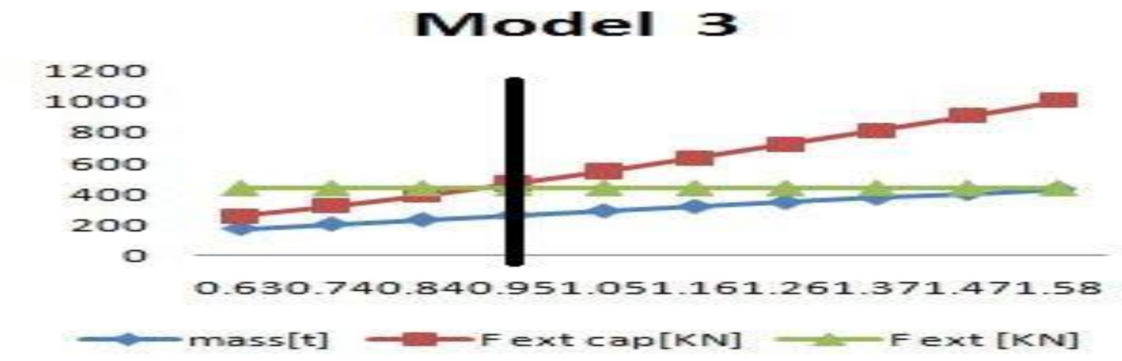
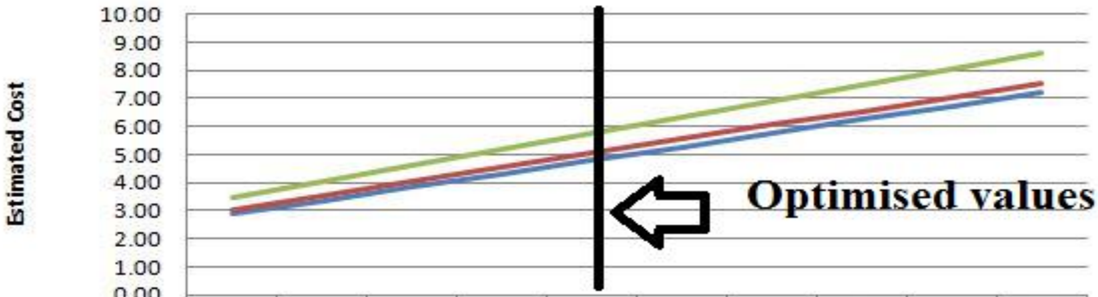


Fig.12. Model 3 mass and forces

All models react different to environmental loads as expected, and these structures are able to withstand forces at different k numbers even if the original project is based on real data from operating rig.

- **Comparative study**

All models presented could be used for a estimated price of 4.80mil$, 5.04mil$ and 5.74mil$ and the difference of almost 1mil$ is huge related to a single parameter of construction. The model no.1 is more likely to be used in offshore construction because the cost is important in the business environment. Expected cost are presented in fig.13 and the lowest values are registered for model no.1 at a value k=0.92 at a corresponding cost of 4.80mil$. This type of study is useful in economical departments and is likely to be handled by a combined team of engineers and economists. For a modified FoS to 1.5 we will choose the first superior value of k and this will be enough to strengthen the structure. Also, in fig.13, we aligned optimized values according k factor to compare costs in all three different situations, all calculated costs are expressed in the table below.



	1	2	3	4	5	6	7	8	9	10
M1[mil $]	2.88	3.36	3.84	4.32	4.80	5.28	5.76	6.24	6.72	7.20
M2[mil $]	3.02	3.53	4.03	4.54	5.04	5.54	6.05	6.55	7.06	7.56
M3[mil $]	3.46	4.03	4.61	5.18	5.76	6.34	6.91	7.49	8.06	8.64

Fig.13. Compared costs in 10 cases presented in fig.10.11 and 12

- **Conclusion**

The new coupled analysis for simplified economical offshore projects is relevant in deciding which model or type of structure to use to obtain the lowest cost of construction. It is a relevant study because solutions can be verified according to exactly boundary conditions and are compared to those found in the literature of register rules. The comparative study for all presented models give the right information regarding the costs related to economical construction of each case. Optimized values shown are closely related to the actual value of k=1, so the initial calculated project is close to the result value. In some cases, as presented, we can obtain a better ratio between cost and project.

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