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STABILITY ANALYSIS OF MODERN OFFSHORE SEMI-SUBMERSIBLES

Ionut-Cristian SCURTU[1]
Mihail PRICOP[2]
Valentin ONCICA[3]
[1] Lieutenant (N) instr. eng. PhD Candidate, Faculty of Navigation and Naval Management, "Mircea cel Batran" Naval Academy, mail: scurtucristian@yahoo.com
[2] Captain (N) (r) Associate professor Eng. PhD, Faculty of Navigation and Naval Management, "Mircea cel Batran" Naval Academy
[3] Commander (Navy) Lecturer Eng. PhD, Faculty of Navigation and Naval Management, "Mircea cel Batran" Naval Academy

Abstract. *Based on a tri-column semisubmersible Autoship analysis will be done on different designs. WindFloat project values are used to draw 3D in AUTOSHIP software. Results from Autohydro component are analyzed and presented related to actual offshore construction and stability requirements. Societies of Classification are imposing rules regarding safety and ways to prevent accidental situations. Based on this analysis the semi-submersible owner can decide if the tri-column semi-submersible is according to imposed stability requirements during operation.*
Keywords*: Autoship, Offshore semi-submersible, Autohydro, Stability.*

INTRODUCTION

The design of semi-submersible structures is a technical process that includes structural and stability analysis. All projects have to be tested and carefully analyzed before operation in real sea in order to ensure the project structural strength and stability for all operating conditions.
In this process, done mainly by the development and design departments, a number of requirements of stability are taken into account and they must be satisfied so that after the materialization of the project to achieve an optimal construction according to classification rules.
The semi-submersibles sector is developing fast and it plays a key role in offshore oil extraction industry due to good sea keeping performances. Most oil industry projects for waters deeper than 30 m are based on semi-submersibles and this type of structure is a remarkable expansion for maritime industry. Based on semi-submersible capabilities, semi-submersible are capable to carry in deeper waters different equipments for renewable energy extraction, like wind and wave energy converters. The resulted energy is needed to supply energy to near shore cities in a higher and higher percent, as requested by EU to all member countries for 2020.
This will be impossible without a stable and secure base structure able to carry energy converters in areas where the visual impact and the interference with the network of maritime transport is minimum and the amount of extracted energy could be maximum.
Projects assessment should be done for all ballast conditions and all sea states in order to ensure investors and shipyards to build and develop environmental friendly technologies like WindFloat. This should be done accordingly to classification rules regarding intact and damage stability and this paper will present the Autoship stability and longitudinal strength evaluation of a three columns semi-stability that can be used in future offshore renewable energy. All presented values are according to presented dimensions of WindFloat structures and can serve as model in different analysis regarding offshore stability and longitudinal strength.

METHODOLOGY AND HYPOTHESES

Semi-submersible model 3D design in ModelMaker

Model maker is a Autoship component designed for easy 3D building of ship models and in this paper it will be used to draw the 3D model of the three columns semi-submersible. Modelmaker is used to produce models stored as Geometry Files (GFs). A Geometry file is a collection of groups of 2D cross sections that together define the entire object. Each group of cross sections, or "part", describes a particular piece of the vessel model - such as a hull or a compartment.
All parts are assigned attributes, such as name, side factor, class, contents, and specific gravity. Any number of parts can be made, but one of them must be named "Hull" - if no part is named Hull, Autohydro cannot process the GF file. All parts are made up of components. Components also take on attributes, such as side designation and permeability. Components may be joined together to produce a single, complex volume. You can fit or trim components with each other. (ModelMaker Documentation)
The model, and the coordinates of the vertices that define it, are shown in Model Maker's main screen. Also included in the main screen are the

tools required to create, edit, or delete the components and parts. You control Model Maker by using the menus, tools, and the extensive list of commands available (commands are input using the CMD (or "Command") Menu, which calls the Command File Editor.

In this paper we will build two semi-submersible models with and without heave plates in order to compare and analyze same draft situation in both cases.

Relationship between Model Maker and Autohydro

ASC's Autohydro product has the capability to analyze the hydrostatic characteristics of any kind of vessel under a wide variety of conditions. It is comprised of two main modules: Modelmaker and Autohydro.

Modelmaker is used to model anything that displaces and/or contains fluids - vessels of any size or configuration, buoys, docks, storage tanks, drilling platforms, etc. Autohydro is used to perform hydrostatic and stability calculations, analyze hydrostatic and stability characteristics for various loading conditions, and to produce graphics and text for reports and tables. (ModelMaker Documentation)

The model that Modelmaker produces is called a Geometry File - it describes the geometry of the floating object. Autohydro analyses that GF file. Beyond this relationship, there is no communication between the two components. Autohydro and Model Maker do not use the same commands, and exchange no data, that is why we have to save the model as GF file.

Semi-submersible model assessment in Autohydro

Autohydro is then used to analyze those models under different conditions.

- Autohydro is a complete hydrostatics and stability calculations program for naval architects, ship designers and marine engineers:
- Autohydro is a true "floating simulator" - it calculates the reaction of a vessel model to specified conditions, which can include loading configuration, damage, wind, and high speed turning momentum (Autohydro Documentation.)
- Vessel attitude is displayed both graphically and in text on the screen.
- Graphical and printed reports can be displayed, edited, printed, saved, or exported to other Windows applications.
- Autohydro can also be used to obtain hull form characteristics and capacities.

SEMI-SUBMERSIBLE 3D MODEL ANALYSIS

Model Maker 3D model

Semi-submersible model 3D created in ModelMaker will reflect all dimensions in order to obtain with maximum accuracy stability details for this case of study and to obtain the possibility of comparing two situations for the same draft.

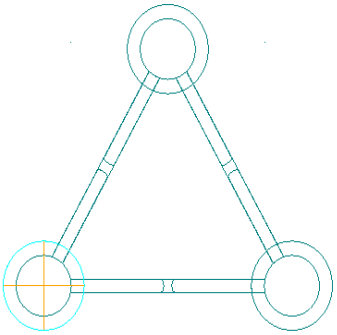

Fig.1. Top view for semi-submersible model 3D with heave plates (ModelMaker)

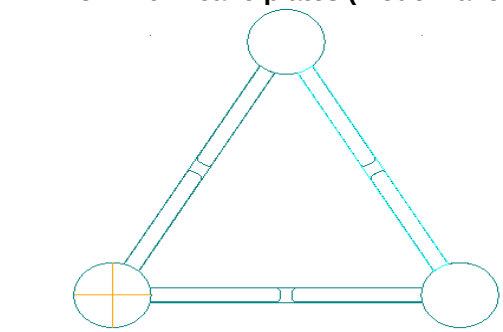

Fig.2. Top view for semi-submersible model 3D without heave plates (ModelMaker)

Fig.3. Side view for semi-submersible model 3D with heave plates (ModelMaker)

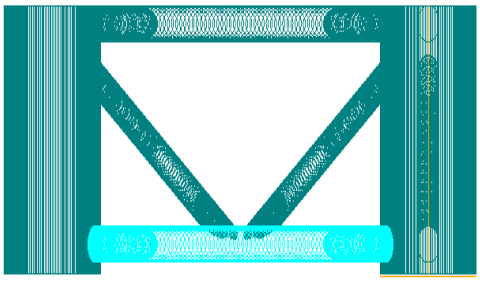

Fig.4. Side view for semi-submersible model 3D without heave plates (ModelMaker)

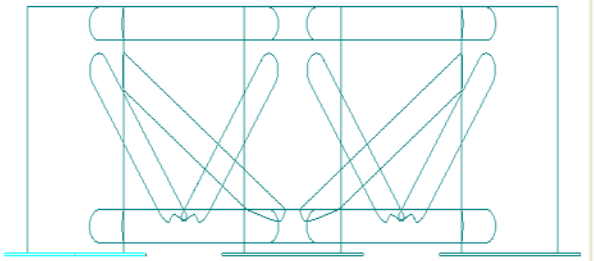

Fig.5. Sketch side view for semi-submersible model 3D with heave plates (ModelMaker)

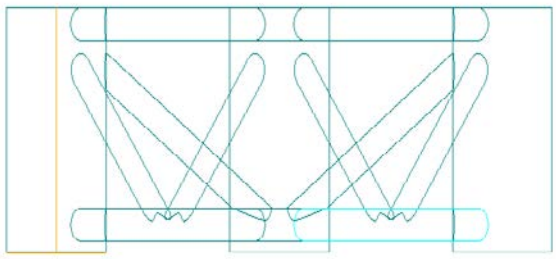

Fig.6. Sketch side view for semi-submersible model 3D without heave plates (ModelMaker)

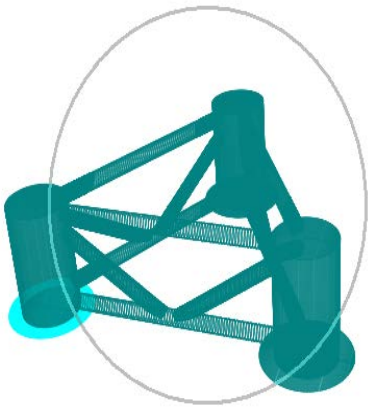

Fig.7. Isometric view for semi-submersible model 3D with heave plates (ModelMaker)

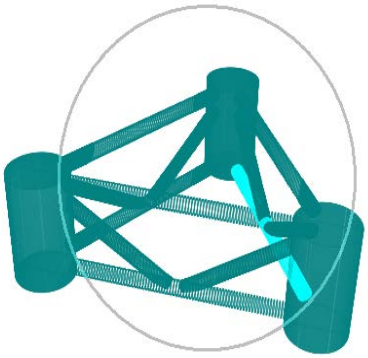

Fig.8. Isometric view for semi-submersible model 3D without heave plates (Model Maker)

Autohydro 3D model

The gf. File previously created in Model Maker will be Imported to Autohydro using command File> Open and all calculations will be done for saltwater in both cases in order to get a similar case of study for semi-submersible with and without heave plates. Both loaded cases are shown in figures 9 and 10.

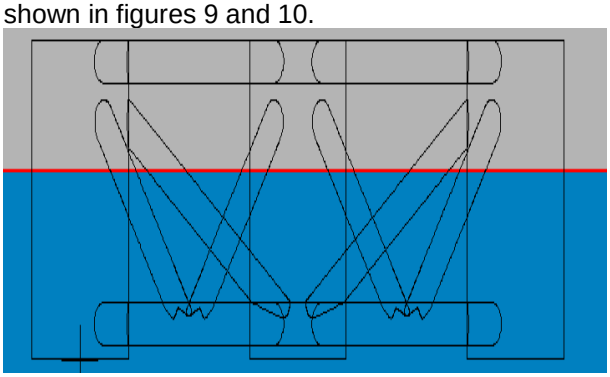

Fig.9. Side view for floating semi-submersible with heave plates (Autohydro)

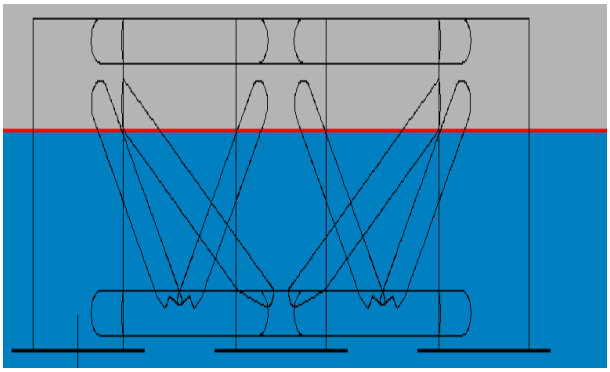

Fig.10. Side view for floating semi-submersible without heave plates (Autohydro)

Autohydro 3D model results analysis

Results for semi-submersible without heave plates

Table.1. Righting Arms vs Heel Angle for semi-submersible without heave plates

Heel Angle (deg)	Origin Depth (m)	Righting Arm (m)
0.01p	11.387	0.000
5.01p	10.212	2.026
10.01p	9.004	4.002
15.01p	8.070	5.096
18.81p	7.632	5.201
20.01p	7.506	5.195
25.01p	7.011	5.044
30.01p	6.535	4.764
35.01p	6.058	4.404
40.01p	5.569	3.991
45.01p	5.063	3.543
50.01p	4.542	3.075
55.01p	4.009	2.605
60.01p	3.441	2.138

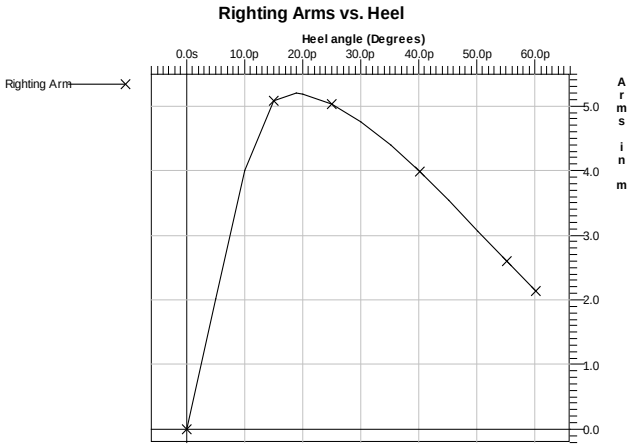

Fig.11. Semi-submersible without heave plates righting arm

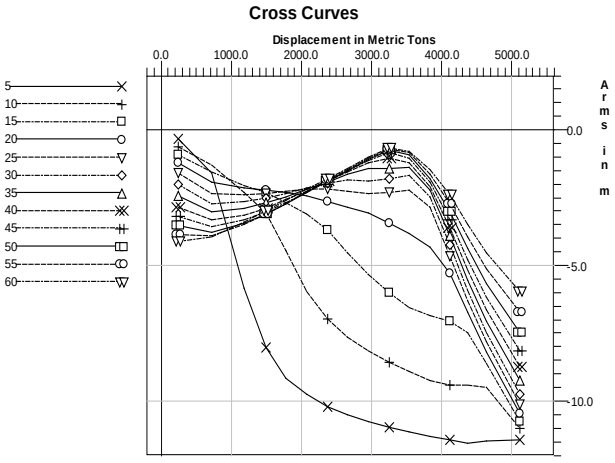

Fig.12. Semi-submersible without heave plates cross curves

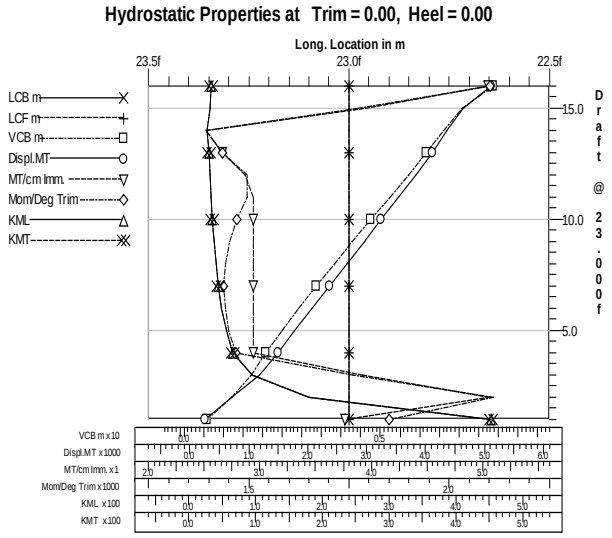

Fig.13. Semi-submersible without heave plates hydrostatic properties

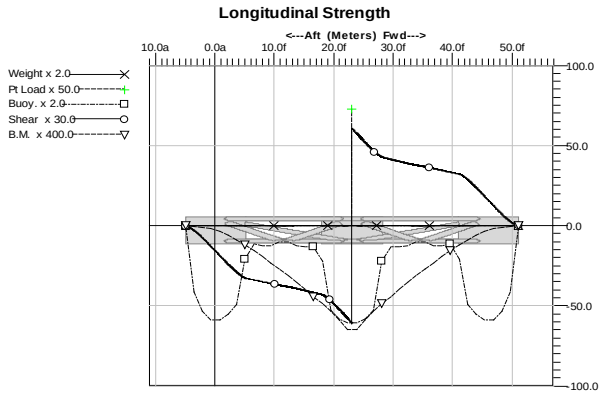

Fig.14. Semi-submersible without heave plates longitudinal strength

Results for semi-submersible without heave plates

Table.2. Righting Arms vs Heel Angle for semi-submersible without heave plates

Heel Angle (deg)	Origin Depth (m)	Righting Arm (m)
0.06p	11.391	0.000
5.06p	10.216	2.068
10.06p	9.006	4.091
15.06p	8.082	5.216
20.06p	7.519	5.481
20.46p	7.478	5.381
25.06p	7.024	5.301
30.06p	6.548	5.092
35.06p	6.070	4.802
40.06p	5.580	4.456
45.06p	5.074	4.073
50.06p	4.558	3.671

55.06p	4.029	3.262
60.06p	3.465	2.851

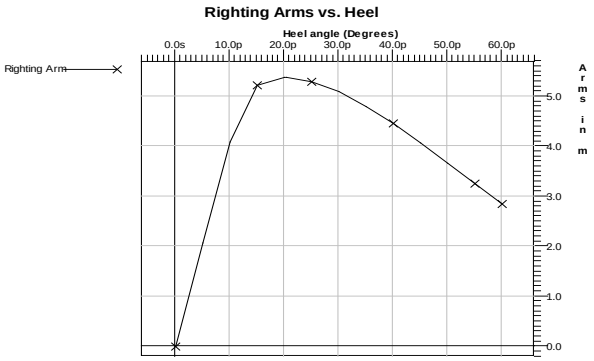

Fig.15. Semi-submersible with heave plates righting arm

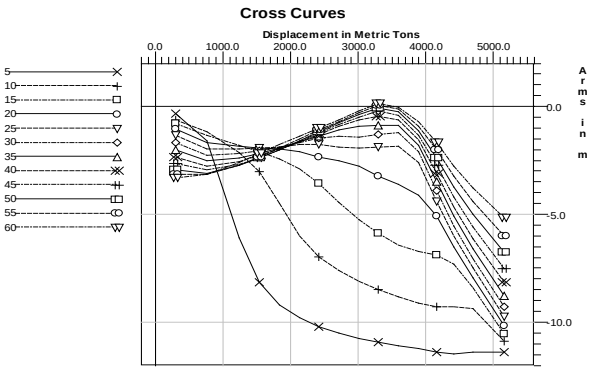

Fig.16. Semi-submersible with heave plates cross curves

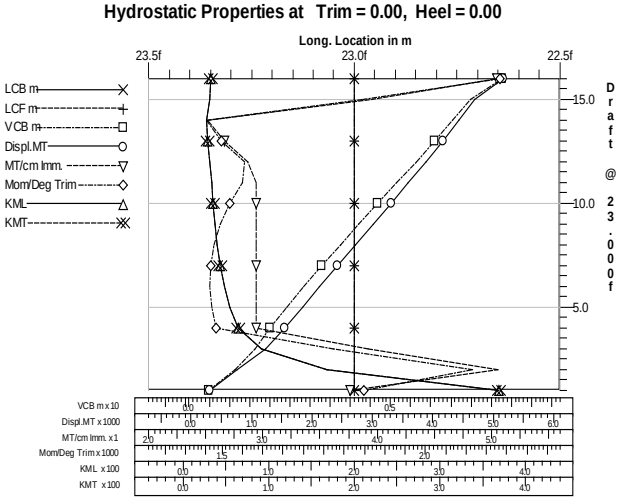

Fig.17. Semi-submersible with heave plates hydrostatic properties

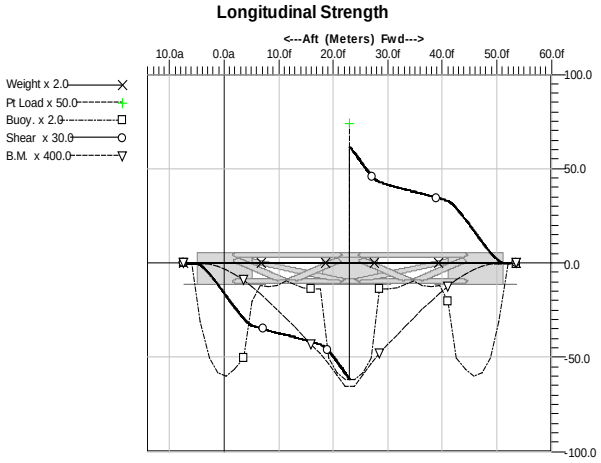

Fig.18. Semi-submersible with heave plates longitudinal strength

Results comparison and analysis

In the presented cases, semi-submersibles have large righting arms in both situations and the use of heave plates lowers the gravity center and increases the righting arm for this situation with 5%. This will decrease angles of roll and will influence the maximum capable external moment for the three columns semi-submersible. The increased bottom area and volume will modify the sea keeping properties and will have an effect on static stability as presented.

Structural design of a semi-submersible involves knowledge related to stability, response to environmental and operational loads, structural strength and safety rules. To asses stability for different ship shapes Autoship package is recommended and used in shipyards and universities worldwide. For the current semi-submersible using the Autohydro mathematical model we can estimate as accurately as possible the static stability in two different design cases for a better understanding the heave plates contribution.

According to Autohydro program and initial data, the 3D design with heave plates is more stable and this feature can be controlled by diameter changes in heave plates design.

CONCLUSIONS

Semi-submersibles described are built with materials and technology borrowed from large offshore oil rigs and few projects were loaded in ModelMaker and Autohydro. Compared with a ship shaped vessel is challenging to use component software from ASC Autoship in assessment of stability of semi-submersibles but not impossible.

We present two comparative designs for the same structure and we concluded that the use of heave plates is recommended for a better static stability as presented. Also the dynamical stability will be improved based on integral relation with static stability. The use of heave plates is appropriate for semi-submersible designs due to the performances presented and is a solution to decrease the waterplane area in various operational cases in marine environment.

Installation of new semi-submersible for wind and wave energy extraction requires a good knowledge of stability issues in accordance with registers and HSE rules.

This document summarizes information on three columns semi-submersibles in development for wind and wave offshore energy extraction.

This work has reviewed stability and reported the state of art in 2015 on the semi-submersible design. In this analysis we have shown that semisubmersible design strong influencing stability in software analysis. This work has presented a stability analysis that can improve software simulations in Autoship for semi-submersibles. The analysis reported in this paper can be further explored to develop semisubmersible related aided design for better stability understanding and development for the offshore structures.

BIBLIOGRAPHY:

[1] ABS. Classification, Certification & Related Services for Mobile Offshore Drilling Units. Available at: http://www.eagle.org/eagleExternalPortalWEB/ShowProperty/BEA%20Repository/References/Capability%20Brochures/MODUCapabilities Accessed 12.12.2014

[2] DNV, Offshore standard DNV-OS-C101 Design of offshore steel structures, general (LRFD method), April 2011

[3] Gerwick B. C. Construction of marine and offshore structures Third edition, CRC press, ISBN 0-8493-3052-1, 2007

[4] Obreja, D., Ship theory ("Teoria navei. Concepte şi metode de analiză a performanţelor de navigaţie"), Editura Didactică şi Pedagogică, Bucureşti, 2005 Clark, C., The Management of Merchant Ship Stability, Trim and Strength, Nautical Istitute, Londra, 2002

[5] Popovici, O., Ioan, A., Domnişoru, L, Construction, development and operation of the ship ("Construcţia, amenajarea şi exploatarea navei"), Universitatea "Dunărea de Jos", Galaţi, 1991

[6] Pitulice D., Dinamica construcţiilor marine, Partea a II-a: Răspunsul platformelor fixe la solicitările mediului marin, Editura EVRIKA Brăila, 1998, ISBN 973-9499-48-1.

[7] Sharma, R., Kim, T.W., Sha, O.P., and Misra S.C., 2009b. Semisubmersible design faces challenges. *Offshore Marine Technology (OMT)*, 3rd Quarter 2009, pp. 22 - 30.

[8] Wen-jun Shen, You-gang Tang, Li-qin Liu , Research on the hydrodynamic characteristics of heave plate structure with different form edges of a spar platform, China Ocean Engineering March 2012, Volume 26, Issue 1, pp 177-184(http://link.springer.com/article/10.1007/s13344-012-0013-5)

[9] *** Autohydro and Model Maker Documentation http: www.autoship.com

[10] *** WindFloat project: www.principlepowerinc.com/products/windfloat.html