Engineering and Technology Journal e-ISSN: 2456-3358

Volume 11 Issue 03 March-2026, Page No.-9164-9172

DOI: 10.47191/etj/v11i03.05, I.F. – 8.595

Development of a Platform for Semi-Submersible Stability Studies

W. A. Akpan[1], W. A. Onuh[2], E. O. Usungurua[3], K.E. Akpan[4], C. M. Orazulume[5], U. S. Umoh[6]

[1]Department of Mechanical Engineering, School of Engineering and Engineering Technology, Federal University of Technology Ikot Abasi, Akwa Ibom State, Nigeria.

[2]Department of Aerospace Engineering, School of Engineering and Engineering Technology Federal University of Technology, Ikot Abasi, Akwa Ibom State, Nigeria.

[3]Department of Mechanical Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Ikot Abasi, Nigeria.

[4]Department of Mechanical Engineering of Mechanical Engineering, Faculty of Engineering, University of Uyo, Akwa Ibom State, Nigeria.

[5]Department of Electrical and Electronics Engineering, Faculty of Engineering, TopFaith University Mkpatak, Akwa Ibom State, Nigeria.

[6]Department of Mechanical Engineering, Faculty of Engineering, University of Uyo. Akwa Ibom State, Nigeria.

ABSTRACT: Stability of a semi-submersible body is of serious concern because of the consequences of the capsize of floating bodies in waters-rivers, sea, and ocean. Understanding the key parameters that affect the stability of a body is crucial to safeguarding such incidences of capsize. Research has shown that the metacentric height, center of gravity and center of buoyance are the key parameters affecting the stability of a semi-submersible body. Practical illustrations of the variations of these parameters with respect to the stability of semi-submersible body is crucial and is the crux of this research work. The design, which is novel in its entirety, developed a platform to enable stability of semi-submersible of a body to be carried out under similar conditions in real life. The Composite system of the design consists of a platform with three legs support in a reserviour of water. The water is supplied by a centrifugal pump connected to a storage tank. The system has a vibrator to generate sea current and wave and a blower to produce wind turbulence. There is a flowmeter to record the exact volume of water from the storage tank via the pump to the reserviour. This composite system was developed and produced for the purpose of this research. With the success recorded, the stability studies of a semi- submersible body has been effectively studied and it is very useful to students and other interested researchers in this area.

KEYWORDS: Stability, platform, semi-submersible, buoyancy, metacentric height, center of gravity.

1.0 INTRODUCTION

Two-third of the earth's surface is covered with water. A lot of human activities are carried out around marine environment. The sea and ocean beds are endowed with abundant natural resources. Most of the equipment and vessels that are used in the marine environment are semi-submersed. Thus, there is the need to study and characterize the behaviour of bodies which are partially submerged in fluids under different flow conditions such as laminar and turbulent flows caused by wind and wave and sea or ocean current.

Semi-submersible bodies in practice constitute specialized marine vessels used in several specific offshore roles such as offshore drilling rigs, safety vessels, oil production platforms, and heavy lift cranes and offshore wind turbine. Semi-Submersibles are used for various purposed in offshore and marine engineering, cane vessels, drilling vessels, tourists' vessels, production platforms floating wind turbine, accommodation facilities. Drillship can also be used for drilling operations in ultra-deep waters because they can hold more equipment, but semi-submersibles are chosen for stability and are designed with good stability and sea-keeping characteristics.

Every semi-submersible body experiences a solid-fluid interaction between the solid and the fluids.

They are mainly chosen for their superb stability in the water. Because semi-submersible float they are easily transported to offshore location by either an external vessel like a barge or by its own propulsion. Semi-submersible can withstand harsh and rough water environments.

Semi-submersible platforms like rigs have high operating cost.

There are many types of semi-submersible bodies like: Tourist semi-submersible, military semi-submersible, deep sea ocean research semi-submersible, offshore drilling semi-

submersible, crane semi-submersible, floating dry dock semi-submersible.
Deep water offshore platforms come in many types: The semi-submersible operating in the range of 1000-2250m, drill-ships in the range of 2250m and tension leg offshore in the range of 2000-2000m, spar offshore in 1500-2500m.

1.1 Stability of semi-submersible bodies
Stability is the tendency of a nit or body to return to its original position after it has been heeled by an external force such as wind or wave. They are three possible conditions of equilibrium for a semi-submersible platform depending on the position of center of gravity relative to the metacenter. It is stable when the center of gravity lies below the metacenter. Neutral if the center of gravity lies at the same position as the metacenter and unstable if the center of gravity lies above the metacenter. [1] conducted research on floating offshore wind turbine (FOWT). The findings indicated that current survivability assessment by area –ratio method may be overly conservative in evaluating FOWTs resistance o capsizing and sinking. Dynamic response-based survivability methodologies were found to be more accurate in evaluating semi-submersible FOWT's resistance to capsizing.
Center of gravity has a serious effect on the stability of submerged bodies. The center of gravity is that point at which the weight of a semi-submersible body and its contents are assumed to concentrate. It is that point about which the body or semi-submersible body like platform will balance. The total weight of the body will act vertically downwards through this point. Buoyancy or upthrust is important as it allows the apparent loss of weight of a body immersed in a fluid. The center of buoyancy is the geometric center of the submerged volume of the body and is the point through which the resultant buoyancy force may be assumed to act vertically upwards.
The stability of a submerged body depends on the metacenter. For example, when a semi-submersible body is heeled the center of buoyancy will move away from the original centerline as it is always the geometric center of underwater (submerged) volume of the unit. A vertical line drawn from the new position intersects the original vertical centerline at a point. This point is called the metacenter. Metacenter is always measured vertically upwards from the center of gravity and can be obtained either from tables of hydrostatic properties or hydrostatic curves.[2] explored and presented a model that showed better hydrodynamic characteristic and resonance avoidance capability.

1.2Turbulence Flow
The flow around an object can either be laminar or turbulent. Laminar flow is characterized by smooth, constant fluid motion, while turbulent flow is characterized by chaotic property changes, such as rapid variation of pressure and flow velocity in space and time. It produces a three-dimensional flow and spawning of unsteady vortices f different sizes or eddies. As a result of interaction between eddies, kinetic energy is continuously transferred from larger eddies to smaller eddies, in a progress known as energy cascade and lasts until the energy is finally dissipated in the smaller eddies. The smaller eddies are influenced by viscous effects, while the larger ones are predominantly driven by inertia effects. The means of differentiating laminar and turbulent flow is by means of Reynolds number.

1.3 Computational Fluid Dynamics
Computational fluid dynamics (CFD) plays important part in analysing problems that involves fluid flow with the help of computer-based simulations. The core of CFD is in numerical algorithms, which are used to solve the governing equations of fluid dynamics: the conservation of mass. Momentum and energy. It involves pre-processing, solving and post-processing. It starts with mathematical expression of physical phenomena, definition of geometry, generation of mesh, definition of fluid properties and establishing initial and boundary conditions. Such equations include the Navier – Stokes equations.
The second element of CFD-process is the stage of solving the Partial Differential Equations (PDEs). There are several techniques available for us like finite difference, finite element method and spectra method. The most established of these methods is the finite volume method (FVM. It consists of discretization of PDEs and then final solution.
Many researches have been carried out over the years on stability of semi-submersible bodies for practical purposes.[1] researched on assessment of intact stability criteria and survivability for semi-submersible floating offshore wind turbine concluded that dynamic response based survivability assessment method was more satisfactory that area –ratio method in evaluating semi-submersible FOWT's resistance to capsizing and sinking of the platform.[2] showed a model with better hydrodynamic characteristics and resonance avoidance resilience.. The drive to deploy wind turbine of semi-submersible platforms have been due to depletion of fossil fuels, making this development inevitable. Floating wind power platforms are classified into four conceptual models: barge, tension, single and semi-submersible. With the use of semi-submersible platform for offshore wind turbine, it is necessary to suppress the oscillatory motion of the floating body. This is vital to ensure the safe and stable operation of the floating wind turbine [3]. Offshore wind platform are mainly affected by wind and current loads which are manifested as pitching, surge and heave. Heave motion is the most obvious for semi-submersible.
Stability analysis of semi-submersible platforms focuses on the ability to resist external forces like wind, waves, ocean current and maintain equilibrium. [4] conducted a stability analysis of a semi-submersible wind turbine based on gyro-turbine coupled model and found out that the swaying motion of the platform in. This affects power generation and also the structural integrity. It may lead to structural fatigue damage.

By 2022 the global total installed capacity of the floating offshore wind power was put at 245.4 Megawatt [5].

In his research [6] showed that passive mooring systems while be to suppress low -frequency motion through non-liner spring characteristics, have limited effectiveness when dealing with disturbances in the wave frequency range.[7] applied numerical method for a combined wind and wave energy system at an intermediate water depth.

In their research [8] explained the basic motions as the result of turbulence conditions on a semi-submersible FOWT to include surge, sway, heave, roll, pitch and yaw. These motions introduce additional dynamics, such as fore aft and lateral oscillations of the tower structure along with corresponding platform movements. Oscillatory motion has a negative impact of FOWTs and reduces the energy efficiency and brings about higher maintenance costs and safety.[9] presented floating platform features distinctive inward concave design at the waterline of its three external columns and this produced a satisfactory result.[10] provides necessary details on the semi-submersible platform. Thrust force, wind turbine weight, wind forces and wave and current forces as the external forces acting on a tri-floater. [11] investigated and found out that more than 80% 0f offshore wind turbines in Europe have adopted monopile foundations, especially in shallow water zones. Similarly, [12] studied the effects of the presence of ambient current on the hydrodynamic forces on moored ships when another vessel passes through the waterway.[13] derived analytical expressions hat described the effect of current on drag forces from large waves and conducted experiments the measured forces on a model jacket in collinear wave and current.

[14] conducted research on the wave current force of platform pile and steel casing in different construction stage sand the horizontal force and bending moment of the foundation under variable wave and current parameters and tested using indoor model.

[15] presented hydrodynamic analysis of the deep wind semi-submersible floating platform in waves based on potential flow theory by considering second order wave exciting force.

The damping characteristics of heave plate with 35^o was studied by [16] and determined the performance of offshore floating wind and photovoltaic on a platform,

In the geometry, triangle based semi-submersible and rectangle-based submersible are preferred. The triangle has geometrical and structural stability with minimum steel consumption and hence less weight. The rectangle has high deck space and transit speed limitation. It possesses geometrical (though less than triangle based semi-submersible) and structural stability with moderate high steel consumption.

The semi-submersible body should be able to withstand various loads like varying and total load. Wave heights, wind speed and sea currents determine the operating sea environment. These factors in design will determine the height of the columns and the air gap between operating water level and the under-side of the operating deck. In the hash maritime environment, height of the columns should be sufficiently increased to ensure that, at survival draft, there is wave impact on the underside of the operating deck. Compared to high column, the low column offers a larger variable load, with all other parameters being equal. An optimum design that optimizes column size and overall rig size to provide the desired variable load and motion is preferred. The final hull design choice is made after a complete structural and hydrodynamics analysis. Initial configuration out of triangle or rectangle is selected by the designer. The ring pontoons are topped with triangular or rectangular columns. The topside deck is supported by the columns with the corners of the topside deck placed at the geographical centers of column tops. The configuration should further be extended with the help of equipment set on triangular deck that is supported by three or four columns with a water entrapment plate at the heel. Other extension of the original configurations can be devised to further provide additional facilities like control, chemical injection systems for subsea wells, power generation systems, and multiphase pumping systems can be added. The design requirements of the semi-submersible consist of owners and shipbuilding yard requirements.

The requirements of the owner are related to the operational aspects, environmental conditions (wind, wave and current) for operations and survival, variable drilling load, total variable load in transit, limitations of motion behaviour: hive, pitch, and roll and sea state for operating conditions. Safety, stability equipment specifications, conversion possibilities and dismantling cost

A semi-submersible design is an iterative process. A preliminary design is selected first and then it is modified in an iterative process to meet the requirements, satisfy the constraints, achieve performance levels and minimize the investment. Since a semisubmersible is a hydrodynamic floating structure that operates at rough and heavy sea weather, its design requires technological and scientific skills from structural mechanics and hydrodynamics. The semi-submersible is subjected to the severe environment loads in high sea state. The data for sea and ocean site is needed for wave height, period, wind speed and current speed for both the operational and survival design condition. The operational and survival design storms are chosen to be 10 to 100 years storm conditions respectively. The shape and height coefficients can be taken from codes of classification societies to research studies, and then applied to the constant topside shapes, the exposed column shapes, and the final component elevations once the final freeboard is calculated.

The wind, current and mean wave drift are applied concurrently in the bow, beam, and quartering directions so that they result in maximum environment loads for operational and survival conditions. The loading pattern for semi-submersible is both local and global. The structural analysis is normally performed with 3D finite element based analytical tools to determine the deflections, moments and stresses acting on the topside, columns, and hull pontoon. The analysis conditions are structure floating at a constant draft and with a static wave with crest of the wave acting on two of the columns opposite from each other produces maximum moments, stresses and deflections. Then the weights of the hull, topside, ballast tanks and nodes are added along with the buoyancy acting on the bottom of the pontoon. The efficient model mooring lines and springs are added to the joint columns and pontoon. The inclusion of wind, wave and current forces in structural analysis produces a dynamic problem. Such dynamic structural interaction produces the reaction forces in the x and y directions. In general, it should be insured that the weights of all the components are equal and opposite force to buoyancy resulting in zero net global displacement in the z direction. The stresses for both wave cases that are created from pressures, weights and buoyancy need to be compared to classification society guidelines. 47.5 to 65.0% of the weights of columns, pontoons and nodes are normally added for safety.

The hull buoyancy is simply the weight of water displaced by the pontoons, nods and parts of the columns that are submerged either during float-on, float-off, operational or survival conditions. The down flooding angles and area ratios for intact stability are needed to be checked as required by classification society guidelines. For damage stability calculations one, two and three consecutive tanks are flooded all the way round semi-submersible. The distance between down flooding angle and the first righting am/ heeling arm intercept under the worst damaged case scenario need to be checked with classification society guidelines. The number of tanks that are floodable o each operational and survival drafts as well as o offset a permanent topside center of gravity that is as far from the geographical center of gravity need be determined. The heave, pitch and roll motion can be determined with either experimental investigations on similar models or CFD simulations. The periods are determined using closed-loop form equations. Normally the heave, pitch and roll are around 16.25-31.25 seconds for normal semi-submersible used in practice. The heave, pitch and roll response can be fund using response amplitude operators computed from a hull of similar dimensions) for the degree headings between 0 to 90. The maximum heave response is found to be from $20-25^o$ heading and is $\pm 2.250m$ - $\pm 2.875m$ and $\pm 3.25m$ - $4.625m$ for the operating 10 years and survival 100 years storm conditions respectively. The maximum pitch and roll response is found to be from $0-3^o$ heading and is $\pm 1.75-\pm 3.125^o$ and $\pm 3.75-\pm 5.25^o$ for the operating 10 years and survival 100 years storm conditions respectively. In ultra-deep water, for a rig it is easy to use a mooring system rather than dynamic positioning. At present, practical considerations of hydrodynamics forces, rules out economically viable drilling rig to carry a self-deploying system in high water depths.

The flow of a fluid through a pipe can impose pressures on the walls of the pipe causing it to deform under certain flow conditions. The deflection of the pipe may lead to structural instability of the pipe. The fundamental natural frequency of a pipe generally in the natural frequency can be very important, such as very high velocity flows through flexible thin-walled pipes such as those used in feed lines to water.

Semi-submersible bodies are widely used in energy exploration. They come in the form of offshore platforms to house workers and machinery needed to drill wells in the ocean bed and extract oil, natural gas; process the fluid and ship them to shore. In recent times floating wind turbines have become prominent. The challenge mostly encountered by semi-submersible bodies is its stability, under different severe wind, wave, and ocean current conditions in addition to operating depths. There is the need to demonstrate this scenario and allow students to appreciate the application of buoyancy and law of floatation on semi-submerged bodies. The objective of this research is to design and produce stability platform environment for experimental studies.

2.0 MATERIALS AND METHODS

The methodology of the design development is categorized as presented.

2.1Design criteria

The critical design that affects the performance of a semi-submersible body include vessel geometry, motions, capacity-variable loads, and total load. Summing these factors to ensure stability and safety is apt.

2.2 Design Conception

The design concept is a triangular solid body with tripod like structural support submerged in a transparent enclosure. The tripod structure is hoisted at the bottom end by a floatation sphere. The composite system is placed in water in the enclosure with inlet and outlets. Water supply to the enclosure is by a centrifugal pump with valves to allow for variability. Turbulence is generated and wind effect applied to depict actual conditions for studies and simulations.

2.3 Design Considerations

The following considerations will be considered in the design of the System.

i. Size of floating body/ enclosure
ii. Maximum and minimum load on the semi-submerged body
iii. Pressure regime to generate flow conditions-especially turbulent flow
iv. Enclosure volume control
v. Fluid losses
vi. Load orientation
vii. External loads e.g., wind

2.4 Materials Selection

Materials selections considered were strength, rigidity, toughness of parts, ability to withstand environmental conditions like corrosion and floatation enhancement,

2.5 Experimental Procedures

(1) Water from storage tank was be pumped into the perspex enclosure to the required volume to sustain the floating body which is anchored.
(2) Specific weights were be placed on the semi-submersible body and the oscillation about the metacenter (M) and the angle of tilt of the plumb bob observed.
(3) The angles of tilt were recorded.
(4) Various flow severe conditions were initiated and data obtained.

.2.6 Design Calculations

From the law of conservation of energy, for a fluid flowing through a conduit:

$$\rho_1 A_1 v_1 = \rho_1 A_1 v_2 \qquad \text{Equation 1}$$

where $A_1 A_2$ are the cross-sectional area

v_1, v_2 are the fluid velocities.

Total inflow to junction is equal to total outflow from junction, therefore.

$$\rho_1 Q_1 = \rho_2 Q_2 + \rho_3 Q_3 \qquad \text{Equation 2}$$

where Q_1, Q_2, Q_3 are the volumes flow rates.

The type of flow in a liquid is expressed using Reynold’s number (Re):

$$\mathrm{Re} = \frac{\rho V R}{\mu} \qquad \text{Equation 3}$$

where, Re is the Reynolds number
R is the hydraulic radius
ρ is the density of the liquid?
V is the average velocity
μ is the coefficient of dynamic viscosity of fluid (water?)
It is the number that will determine if the flow is laminar (smooth) of turbulent (rough and wavy).

2.7 Floating bodies

For a floating body, the forces acting are the upthrust(R) acting through the center of buoyancy and the weight of the body.

The weight (W) acting through the center of gravity is expressed a:

$$W = mg \qquad \text{Equation 4}$$

where m is the mass of the body and g is the acceleration due to gravity.
For equilibrium, R and W must be equal and act in the same line.
R is expressed as:

$$R = \rho g V$$

where V is the volume of the fluid displaced is further is given as:

$$V = \frac{mg}{\rho g} = \frac{m}{\rho} \qquad \text{Equation 5}$$

2.8 Stability of a submerged body

The stability of the body depends on the position of the center of gravity and center of buoyancy relative to the metacentric height (GM). Figure 1 shows a schematic diagram for stability studies of semi-submersible body.

The metacentric height is defined as:

GM=KB+BM-KG Equation 6

where KB is the height of buoyancy from keel and BM is metacentric radius
KG is height of G from keel.

GM is similarly defined as:
GM=MB-GB Equation 7
where MB is the distance between center of buoyancy and metacenter and GB represents the distance between center of buoyancy and center of gravity.

$$BM = \frac{I}{V} \qquad \text{Equation 8}$$

where I is the waterline moment of inertia and V is the submerged volume.
KG is height of G from keel.
Positive GM means stability while negative means instability. When GM is zero the system is in neutral equilibrium. Figure 1.0 illustrate the basic stability principle with respect to metacenter, center of gravity and center of buoyancy.

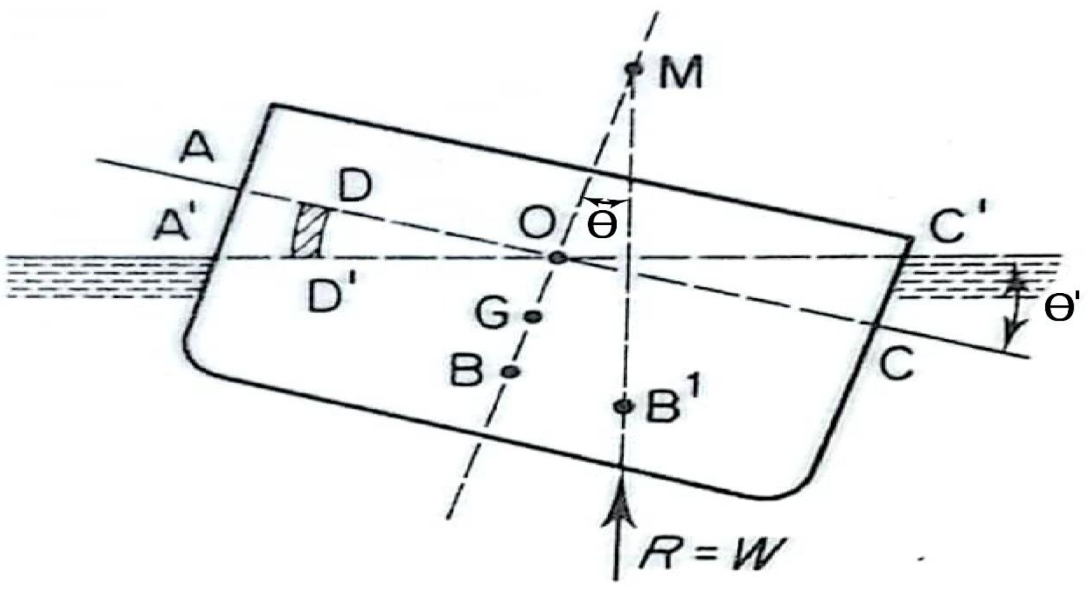


Figure 1.0: Stability Principle

If M is the (metacenter) point at which the line of action of the upthrust (R) cuts the original vertical line through the center of gravity of the body G, the displacement x from G with M and the inclination θ, where the vertical line through G makes with the M after tilt is expressed as:

$$x = GM\theta$$

Equation 9

(i) If M lies above G, a positive moment is produced, and the body is stable.

(ii) If M lies below G, an overturning negative moment is produced, and the body is unstable.

(iii) If M coincides with G the body is in neutral equilibrium.

2.9 Center of gravity

KG or G center of gravity is expressed as:

$$KG = \frac{\sum w_i z_i}{w}$$

Equation 10

KG or G is the vertical position of the center of gravity, w_i is weight of individual components

z_i is the vertical distance of each component of weight from a reference point.

2.10 Metacenter and center of buoyancy

The geometric center (centroid) of the submerged volume of the body is the point where the buoyant force F_d acts.

$$KB = \frac{V_s}{A_w} \times \frac{1}{2}$$

Equation 11

where V_s is volume of submerged part and A_w is the area of waterplane. Equation 11 is suitable for simple shapes like boxes or determined by the hull shape.

KB is the vertical height of the center of buoyancy from the kneel.

2.11 Metacentric Radius (BM)

The distance from the center of buoyancy (B) to the metacenter (M) is known as the metacentric radius.

If B is the point below the center of gravity where the metacenter (M) is above it, and all of them-center of gravity, metacenter and buoyancy lie in the same vertical line. If a tilt with a positive moment exists and the tilt makes the new waterline plane to make an angle θ, with the original waterline and has caused B to move to another position B^1 then,

$$BM = \frac{BB^1}{\theta} = \frac{I}{V}$$

Equation 11

where BM is the metacenter radius, I is the second moment of area of waterline plane, and

V is the volume of liquid displaced (submerged volume).

2.12Flow and Wind Effect

Flow and wind are external are external environmental forces that influence floating objects stability and motion, but they do not directly change the inherent static metacentric height (GM) of the object. They apply external moments (heeling moments) that cause the object to incline (roll or list) and the metacentric height determines how the object responds to these forces. Keeping the metacentric height very high is of immense benefit.

2.13 Periodic time of oscillation

An oscillation when present will produce a periodic time (t) is given as:

$$t = 2\Pi\sqrt{\frac{displacement}{acceleration}} = 2\prod\sqrt{\frac{\theta}{GM\theta g / k^2}}$$

k is the radius of gyration. It is defined as

$$k = \sqrt{\frac{I}{A}} \qquad \text{Equation 12}$$

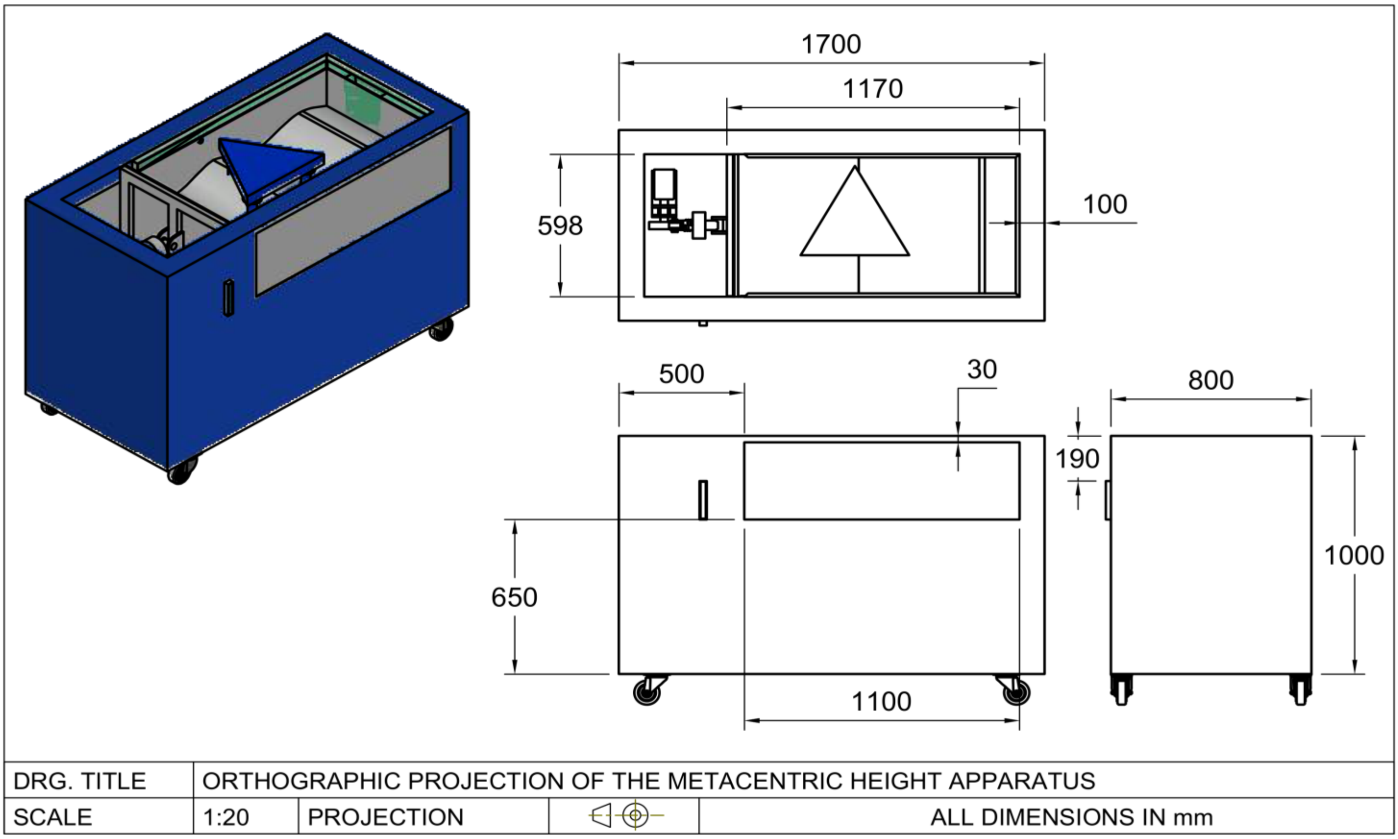
where A is and I is the moment of inertia.

3.0 RESULTS AND DISCUSSION

The results and discussion are presented herewith.

3.1 Results.

The detailed designs of the research are shown in in Figures 2 and 3 respectively.



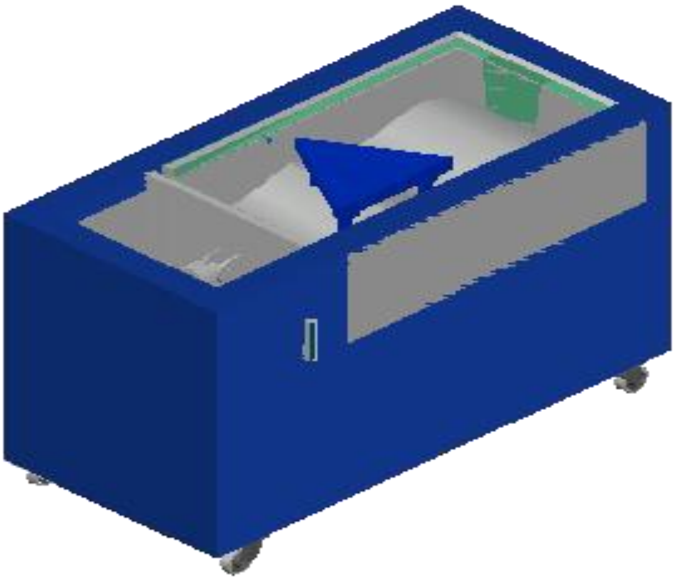
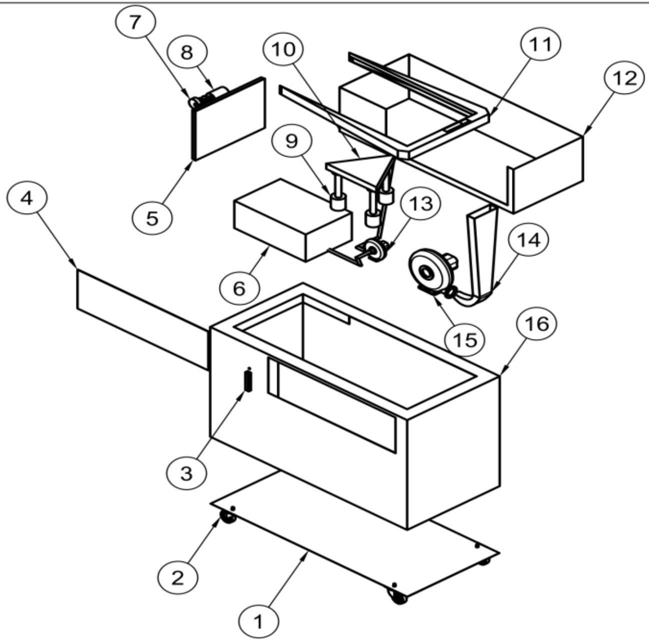


Figure 2: Orthographic Projection of the Metacentric Height Apparatus



S/N	ITEM	DESCRIPTION
16	TANK CASING	MILD STEEL
15	BLOWER	BOUGHT OUT
14	DIFFUSER	MILD STEEL
13	WATER PUMP	BOUGHT OUT
12	MAIN TEST TANK	MILD STEEL
11	AIR SUPPLY DUCT	MILD STEEL
10	META. PLATFORM	MILD STEEL
9	FLOATER	PP
8	DRIVE MOTOR	BOUGHT OUT
7	CAM	MILD STEEL
6	WATER TANK	HDPE
5	WAVE GENERATOR PAD	MILD STEEL
4	SCREEN	PERSPEX
3	FLOWMETER	BOUGHT OUT
2	CASTOR	BOUGHT OUT
1	APPARATUS BASE	MILD STEEL

PARTS LIST

PROJ. TITLE	METACENTRIC HEIGHT APPARATUS	
DATE	FEBRUARY, 2026	
SCALE	1:30	ALL DIMENSIONS IN mm

Figure 3: Metacentric Height Apparatus

3.2 Discussion

The novel stability platform studies consists of- base, castor wheels, flowmeter, screen, wave generator, pad, water tank, cam, motor driver, floater, meta platform, air supply duct, main test tank, water pump, diffuser, blower, and tank casing. The stability apparatus is a compact unit. Water for the main thank is obtained from the storage tank through a pump, metered before entering the main tank. The main tank has a current and wave generator, blower, triangular platform as the basic units. The composite system enables the variation of metacentric height, buoyancy center and center of gravity for experimental studies and demonstrations, when various loads under different operating conditions are applied.

4.0 CONCLUSION

The design presented here is novel and unique to enable effective studies of s submersible body in water under severe conditions of wave and wind which are real life factors where vessels are experiencing in transit and even when anchored. The stability platform has been produced and subjected to test. The test results have met with the design objectives.

ACKNOWLEDGEMENTS

We sincerely thank Tertiary Education Trust Fund (TetFUND), Nigeria for granting approval for this research work. We also thank the management of the Federal University of Technology Ikot Abasi, Akwa Ibom State, Nigeria, especially the Vice Chancellor Prof. Leo Daniel for being a great facilitator for this research work.

.

REFERENCES

1. Kuan-yi wu, Amir N. Donghui C. kAi- Tungma (2025) In: Assessment of intact Stability Criteria and Sustainability for Semi-Submersible FLOWT *Proceedings of ASME 44nd International Conference on Ocean Offshore and Arctic Engineering*, June 22-27, Vancouver, Brtitish Columbia, Canada
2. Hongx, Z., Xiangwu and Zhou (2024) Exploring motion stability of a Novel Semi-submersible Platform for Offshore Wind Turbines Energies Volume 17 (3): https://doi.rg.org/103390/en1702313.
3. Wei W. , Jingyi H., Cheng, Z., Yonghe, X.,Xiwu G. and Dingliang J. (2025) Multi-Column Semi-Submersible Floating Body Hydrodynamic Performance Analysis, Energies .https://doi.org/10.3390/en18081884.
4. Wancheng, W., Hao, L., Yihang, Y., Kai S. and Liing C.(2022) Stability Analysis of Semi-Submersible Floating Wind Turbine Based on Gyro-Turbine Coupled Dynamic Model Frontiers in Marine Science ;30 June , 2025 DOI:10.3389/FMARS.2025I597408.
5. Cao, Q, Xiao, L., Cheng, Z., Liu, M. Chen, Y. and Zhang , K. (2023) *Research n Conceptual Design and Performance Analysis 10 MWSPIC Concept Floating Wind Turbine Foundation in Intermediate*

Water Depth. J. Renew. Sustain Energy 15,066603, di:10.1063/5.50161913.

6. Bai, D. Wang,B. Li, Y. and Wang, W.(2025). Study on Load Reduction and Vibration Control Strategies for Semi-Submersible Offshore Wind Turbines. Sci Rep doi:10.1038/s4159.025-85476-3.
7. Lee C. F. and Ong. M.C. (2025) *Numerical Analysis of Mooring Systems for Reducing Peak Moving Line Tensions in a Combined Wind and Wave Energy System at an Intermediate Water Depth.* Ocean Eng. 325, 120767.doi:10.1016/J.ocean eng-2025.120767.
8. Tong C., Yongbo P., Yifeng, L. (2025) Reliability Analysis of Floating Offshore Wind Turbine Structure Under Extreme Wind-Wave Loads Using the Hybrid *TMDI Conference 14th International Conference on Structrural Safety and Reliability –* ICOSSAR '25'
9. Payam A., Aitor, J. Gamido, Izaskun G, Dong, T. N., Zheu, G. (2023) Hydrostatic Stability and Hydrodynamic of a Floating Wind Turbine Platform Integrated with Oscillating Water Column : A design Study.
10. HONGXU Z., Xiang W. and Zhou Z. (2025) *Exploring Motion Stability of a Novel Semi-Submersible Platform for Offshore Wind Turbine* Journal of Energy Volume 17 Issue 10 10.3390/n17102313.
11. AI generated definition (2024) Based on: Encyclopedia of Renewable Energy Sustainability and the Environment (First Edition)
12. Shan Liu, Zhenyu L. Influence of Currents in the Bearing Wave-Forces Acting on Monopiles Over an Impermeable Slope Journal of Sustainability , Volume 5, 1, 10.33390/su15010129.
13. Mohamad S.H., Ali D., Arne V. H. DANO, R.(2025) Ship –Induced Wave Forces on a Moored Ship in the Pressure Uniform Current, Costal Engineering Volume 198,.
14. Aidan, J.A., Paul, H. t., Hugh W., Jana, O., Saishual, D.(2025) *Harmonic Decomposition of Forces and Estimate of Reduced Mean Flow in Jackets Subjected to Waves and Current* Journal of Fluid Mechanics, Volume 1009, Cambridge University Press.
15. Ling, L. Ling, Y. and Xiao-Fu, X. (2023) Water Current Force Test of Deep Water Foundation of Bridge in Marin Environment , Front Earth Science Volume 10 htpps://doi.org/10.3389/feart.20221053190
16. Ye-Hsien, L. and Cheng-Hao,Y. (2020) *Hydrodynamic Simulation of the Semi-Submersible Wind Float by Investigating Mooring Systems in Irregular Waves.* Journal of Applied Science, Volume 10, Issue 12, 10.3390/app/10124267
17. Junwei, Q. (2023) Design and Analysis of Semi-submersible Offshore Floating Wind and Photovoltaic Platform Di: 1054097/hset. V291.4209.