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Extended Abstract

Numerical Analysis of SPAR Rig Performance via Vortex

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Abstract

Among the various types of offshore rigs, single-point anchor reservoir (SPAR) rigs are notable as exceptional engineering accomplishments. A challenge faced by SPAR rigs is the impact of vortex effects from the surrounding environment. The helical strakes positioned on the body of the SPAR rig serve to reduce these effects. This research aims to examine the vortex phenomenon along with the forces generated by environmental flow waves (specifically lift and drag forces) that act on offshore SPAR rigs through numerical analysis. For the computational fluid dynamics (CFD) simulations, laminar flow conditions were chosen, eliminating vibration and oscillation around a modeled SPAR rig. The simulation was carried out using STAR-CCM+ software to analyze the vortex effects around the SPAR rig both with and without the presence of spiral rings. The results from the numerical simulation suggest that a carefully designed array of helical strakes can significantly impact the reduction of the vortex effect and the direct influence of waves on the rig's structure. Moreover, the water velocity can greatly influence the dynamics of lift and drag forces depending on whether helical strakes are incorporated or not. Consequently, the behavior of lift and drag on the spar structure varied based on the performance of the vortex effects across different components of the spar rigs. Additionally, water velocities of 0.5, 0.75, 1.00, 1.25, and 1.5 m/sec at depths ranging from 1.7 to 2.7 m can significantly impact lift and drag forces, whether strakes are present or not.

1. Introduction

Single Point Anchor Reservoir (SPAR) rigs are massive columnar rigs consisting of a large cylinder. The deck of such rigs typically has a fixed platform that supports drilling equipment and weighs approximately 20,000 to 35,000 tons. The bulk of such rigs, which look like an iceberg below the water surface, is supported by spiral rings or strakes that are installed on the spar rig base. Spiral rings have a significant effect on minimizing the vortex effect on spar rigs in offshore environments that experience strong water currents [1]. Also, the addition or removal of this type of external geometric equipment will have a significant effect on the vibration caused by the vortex effect [2]. This is because the effectiveness of helical strakes is related to the more effective control of the vortex-induced motion affecting the spar rig structure in deep water [3]. In the meantime, one of the notable points in the design of helical strakes is the deep-water inlet of such rigs, which is less affected by wind, waves, and currents even when operating in the worst weather conditions. Such an effective feature can facilitate operation on the upper deck and the drilling equipment located on it. Therefore, the cylindrical body of these rigs acts as a protective factor when using risers and equipment, making floating column rigs an ideal option for developing the exploitation of fields

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located in deep waters.

2. Methodology

To accurately analyze the effect of flow-induced vortexes on the spar rig, simulations of such environmental factors have been performed using STAR CCM+ software. STAR CCM+ software is one of the advanced tools in the field of computational fluid dynamics (CFD) that allows the analysis of unsteady flows and a detailed examination of hydrodynamic forces. The simulations performed using the Volume of Fluid (VOF) method have been used to model two-phase flow. The aforementioned computational method is able to simulate the behavior of fluid flow and its interface with high accuracy. In order to perform the proposed simulation, boundary conditions and special conditions have been considered, which will be explained forward.

3. Boundary Conditions in CFD Simulation

In computational fluid dynamics (CFD) simulations, it is essential to determine the appropriate boundary conditions to define the flow behavior at the boundaries of the computational domain. In this study, a detailed meshing was performed according to the boundary conditions and in accordance with Table 1, based on the use of previous valid research [4], in addition to a sensitivity analysis of the number of meshes. The boundary condition created was used to determine the value and direction of the fluid velocity at the inlet of the computational domain. The range of inlet velocities used in the simulation was considered to be 0.5, 0.75, 1.00, 1.25, and 1.5 m/s, based on values confirmed in previous research [5].

5. Conclusions

1- The validation results demonstrate that the numerical model implemented in STAR-CCM+ is capable of predicting dynamic behavior with acceptable accuracy. Given the good agreement between the numerical results and experimental data, it can be concluded that the method employed in this simulation is sufficiently accurate and suitable for further analysis.

2- Based on the simulation analysis, at various flow velocities (0.5, 0.75, 1.00, 1.25, and 1.5 m/s), the behavior and velocity distribution are similar, differing only in the magnitude of the velocity.

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6. References

[1] Finn, L.D., Maher J.V., & Gupta H., (2003). The Cell Spar and Vortex Induced Vibrations. Paper Presented at the Proceeding of the Offshore Technology Conference (USA), Houston, Texas. https://doi.org/10.4043/15244-MS

[2] Holmes, S., (2009). Predicting Spar VIM Using CFD. Paper Presented at ASME 2008 27th International Conference on Offshore Mechanics and Arctic Engineering (Portugal), Estoril (pp. 895-900). https://doi.org/10.1115/OMAE2008-57706

[3] Roddier, D., Finnigan, T, & Liapis, S., (2009). Influence of the Reynolds Number on Spar Vortex Induced Motions (VIM): Multiple Scale Model Test Comparisons. Paper Presented at the Proceeding of Proceedings of the ASME 2009 28th International Conference on Ocean, Offshore and Arctic Engineering (USA), Honolulu, Hawaii, (5, pp. 797-806). https://doi.org/10.1115/OMAE2009-79991

[4] Irani, M., Perryman, S., Brewer, J., & McNeill S., (2009). Vortex Induced Motions of the Horn Mountain Truss Spar. Paper Presented at the Proceeding of Proceedings of the ASME 2009 28th International Conference on Ocean, Offshore and Arctic Engineering (Portugal), Estoril (pp. 967-973). https://doi.org/10.1115/OMAE2008-57992

[5] Blevins, Robert D. (1994). Flow-induced vibration (2th ed.). New York: Van Nostrand Reinhold. ISBN: 978-0-08-044954-8