

# **AURORA BOREALIS, POLAR RESEARCH & DRILLING VESSEL: PROPULSION & STATION KEEPING IN SOLID DRIFT ICE**

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## *ABSTRACT*

*This paper discusses the propulsion and stationkeeping aspects in the design and development of the AURORA BOREALIS (AB), a dynamically-positioned Polar Research and (Scientific) Drill Vessel for the European Polar Research Icebreaker Consortium (ERICON).*

*The design of the vessel was contracted with Waertsilae Ship Design Germany (WSDG) under the project management of Alfred Wegener Institute for Polar and Marine Research (AWI).*

*The AB is a heavy icebreaker of the highest ice class. She is powered to break continuously in more than 2.5 m of multi-year ice and is able to manage ridges up to 15 m. The ship is designed to perform research tasks including scientific drilling year-round in the Arctic and Antarctic without any support vessels.*

*The key issue in the performance specification of the vessel is the mandatory requirement of performing stationkeeping operations in drifting solid ice of more than 2.0 m thickness during drilling and other research tasks.*



*This paper presents and discusses some of the design challenges and problems, as well as the test results and design solutions. It includes selected results of the ice tests for stationkeeping in drifting solid ice of up to 2.0-meter thickness, i.e., icebreaking in a practically stationary mode, which were carried out in two ice tanks in Helsinki and Hamburg.*

*For the various propulsion tasks -- transit at 16 knots, icebreaking, and stationkeeping in ice -- a propulsion system is installed totaling 108,000 kW. The selected propulsion arrangements is described and several alternate propulsion concepts are discussed.*

*Conclusions: A great amount of propulsive power is required to implement the tasks of stationkeeping and icebreaking applying conventional ice breaking techniques, i.e., providing icebreaking forces through propulsors. As an alternative, the breaking of ice in stationary mode of the vessel by means of induced motions on the vessel was investigated.*

*Based on the results of the AB design effort, we conclude that stationkeeping operation in solid drift ice is feasible.*

*Currently, several leading oil companies are conducting research regarding exploration in Arctic waters. The presented results are of significant importance for all projects dealing with stationkeeping of offshore vessels in ice. The results are a valuable addition to the database of knowledge regarding Arctic vessels in general and, in particular, stationkeeping in ice.*

## **INTRODUCTION**

*"Research in the polar regions can only be carried out by sophisticated research vessels. Modern research vessels that are capable of penetrating into the central Arctic are rare. A new state-of-the-art research vessel is therefore urgently required to fulfill the needs of European polar research - AURORA BOREALIS.*

*There have been no comparable vessels available for the design and construction of the AURORA BOREALIS. The combination of an icebreaker, drilling ship and multi-purpose vessel - for use in polar regions as well as in the open seas in all seasons - therefore requires the development of new technical concepts.*

*The AURORA BOREALIS project is currently pursued on a European level in the European Polar Board (EPB) of the European Science Foundation (ESF). The EFS provides the necessary financial resources and coordinates the European Research Icebreaker Consortium - Aurora Borealis (ERICON - AB).*

*Ten European nations including 16 partners, e.g., funding agencies, scientific institutions, and companies participate in the AURORA BOREALIS project".*

(Source: ERICON website).

The AURORA BOREALIS is a multipurpose research vessel for worldwide operation. The vessel was designed to meet current and future requirements of the ocean research community, and shall be prepared to comply, as far as feasible, with future rules, regulations and limitations imposed by environmental protection agencies in the decades ahead.

The AURORA BOREALIS is unique. Never in the history of naval architecture was a vessel designed for the mission scope of the AURORA BOREALIS, ranging from heavy icebreaking to scientific deep-ocean drilling while the vessel is captured in solid, drifting sheet ice. During drilling missions (and other operations) in open water, the vessel is automatically positioned. The forces acting on the vessel due to ice

drift, winds, current, and waves are counteracted with the vessel's high-powered propulsion system.

During stationkeeping in solid, drifting sheet ice it is anticipated that the position of the vessel will be initially controlled manually (in joystick mode of the DP control system) until new technologies are available from the DP control system manufacturers. Due to the very slow changes in drift ice angle and velocity, a manual control is feasible and safe.

## **DESIGN**

The development and design of the vessel was contracted with Waertsilae Ship Design Germany (WSDG) (former SCHIFFKO) in Hamburg. WSDG was responsible for the total design scope of the vessel, including the hull design optimization for icebreaking and transit operations, and the stationkeeping concepts. As the designers of the outstandingly successful Polar Research Vessel POLARSTERN, WSDG was the logical candidate for the design of the AB. The design and development program was managed and supervised by the scientists and engineers of the current operator of the POLARSTERN, the Alfred Wegener Institute for Polar and Marine Research (AWI).

The WSDG's design effort of the vessel took over 18 months. An extensive program of ice model tests in two leading institutes confirmed the validity and quality of the WSDG design concept. An unparalleled period of 27 days of model testing explored any possible aspect of the interaction of a vessel with the surrounding ice - while icebreaking or attempting to keep station in drifting ice.

## **SCOPE**

The design of the vessel included a myriad of tasks and design challenges. This paper focuses on the specific task of selecting the propulsion concept and

# STUDENT DESIGN OF A SEMI-SUBMERSIBLE FLOATING PRODUCTION SYSTEM FOR THE GULF OF MEXICO

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## ABSTRACT

*This paper describes the design of a semi-submersible floating production system in the Gulf of Mexico. The platform was designed to produce 100,000 barrels of oil per day in 2440 m of water. Detailed analysis for both 10 year and 100 year storms was performed, and a robustness check was done for a 1000 year storm. The design elements considered were; topside design, safety, buoyancy/trim, stability, loading, structure, cost, and mooring. The hull of the semisubmersible consists of four square columns with filleted edges and pontoons that connect the columns. The topsides were designed to hold the production equipment, helideck, lifeboats, and quarters and have 25m air gap from the waterline so that the platform can continue production in a 100 year storm. The hull displaces 61,000 metric tons, and is ballasted down to a 35 m draft in order to have an acceptable air gap. General Hydrostatics Software was utilized to make sure our semi-submersible complies with American Bureau of Shipping's stability rules for Mobile Offshore Drilling Units. The structural design was analyzed and refined using Visual Analysis, accounting for both static loading and dynamic loads. The analysis of the structure shows 17 cm deflections in both the topsides and the hull, which are acceptable. The mooring analysis was performed with OrcaFlex which was used to optimize the number of lines, line size, and line spacing based upon the American Petroleum Institute's (API) recommended practices. After conforming to API's guidelines, the optimal mooring system was composed of 12 chain-poly-chain lines anchored with suction piles. The total cost of the semisubmersible is estimated at \$1.7 billion.*

## INTRODUCTION

To achieve an optimum design, the semisubmersible went through several stages of iteration. This iteration was done by means of a design spiral as shown in Figure 1 where each design improves upon its predecessor. For example, the draft, computed in hydrostatics, was required to calculate environmental loading, which was used to determine dynamic stability.

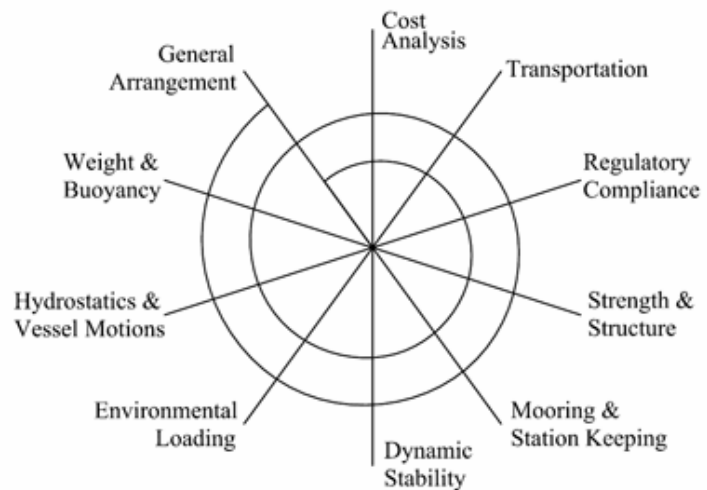


Figure 1: Semi-Submersible Design Spiral

# **THE USE OF DRAG EMBEDMENT ANCHORS IN ARCTIC CONDITIONS**

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## *ABSTRACT*

*The arctic poses a new frontier for the offshore industry and for the use of drag embedment anchors (DEA). Challenges for DEA are the environment, specifically the low temperature and the encountered seabed conditions. DEA can be used successfully in this environment. The low temperature requires careful selection of the materials used in the fabrication - for example impact testing at lower temperatures - but the materials are available for DEA fabrication. Typical seabed conditions in the arctic areas are hard clays and dense sands, formed by ancient glacial activity. For these types of soils a suitable DEA has to be selected that is capable of embedment in these soils. Experience from other areas of the world with hard soils can be used in selection of the DEA for these conditions. This paper will detail the DEA selection both with regards to the materials used in the fabrication and the type of DEA most suitable for the seabed conditions.*

## **INTRODUCTION.**

When using DEA in arctic conditions, care must be taken in selecting an appropriate anchor that is suitable for the specific conditions (temperature and seabed). This paper describes the seabed conditions that can be encountered and the anchor that is suitable for such an environment. Also material selection is important as the low temperatures have an effect.

## **ANCHORING IN HARD SOIL CONDITIONS.**

In Arctic locations it is very common to encounter hard soil conditions. These can be dense sands, very hard clays, gravel or combinations of these. The origin of the soils can be found in glacial activity in the past and the action of icebergs. These soils have a high resistance against penetration and as such DEA penetration will also be limited. As such a DEA for these types of soils should be designed with sufficient structural strength to withstand the design loads on the fluke tips.

For hard soil conditions (limestone, rock, calcarenite, corals and cemented carbonate sand) the Stevshark Mk5 anchor (see Figure 2) has been

developed. The Stevshark Mk5 anchor is the same anchor as the Stevpris Mk5. The Stevshark Mk5 anchor is however adapted to penetrate hard soils. The anchor can be equipped with a serrated shank, sharp fluke edges and sharp fluke points. In very hard soil the anchor may only partly embed. Therefore the fluke points are specially reinforced to withstand high point loads.

Compared to the Stevpris Mk5 anchor, the Stevshark Mk5 anchor is fabricated using thicker steel plates. The thick steel plates prevent damage when the anchor is handled in very hard soils. Therefore a 12 mT Stevshark Mk5 anchor is slightly smaller in dimensions compared to a 12 mT Stevpris Mk5 anchor.

With respect to holding capacity in hard soil a much more conservative approach is desired, compared to 'standard soil conditions'. Test and all the field data on anchor performance in rock, calcarenite, corals, limestone and sandstone have demonstrated the following with respect to Stevshark Ultimate Holding Capacity (UHC) in these types of soil. Here the UHC is expressed in anchor efficiency (ratio between UHC and anchor weight). Depending on the encountered soil conditions, the thickness of loose sediments on top of the hard soil and the hardness of the hard layer, the efficiency values used for the Stevshark Mk5 anchor

# **DP VESSEL PASSIVE QUICK RELEASE CONTINGENCY MOORING SYSTEMS**

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## *ABSTRACT*

*As offshore fields become more densely occupied with energy infrastructure, it has become necessary to more closely examine the risks and associated consequences of deepwater operations that were previously deemed acceptable. As moored MODU (Mobile Offshore Drilling Unit) risk assessments have evolved, the utilization of DP (Dynamically Positioned) vessels is often perceived to be a “safer” alternative. However, when examining historical statistics for sudden hurricanes with respect to DP vessel T-time, drive offs, and drift offs in a modern drilling scenario, the idea of DP operations being lower risk alternatives is often far from true. This paper will utilize statistical information for failure probabilities and associated consequences for a conventional DP drilling operation in comparison to a DP drilling operation utilizing a passive contingency mooring system. Although the main driver for DP contingency mooring systems should be risk mitigation, considerable savings may be seen by operators through less DP thruster use, reducing fuel costs. A properly designed contingency mooring system could be used to keep station under normal operating conditions, allowing considerable cost savings until larger storms arrive at the drilling location.*

*The principle function of a contingency mooring system for DP vessels is to mitigate the risks associated with operating events, not extreme weather events, such as hurricanes. Given that purpose, a reliable emergency quick release is discussed within this paper as an integral part of the contingency mooring system. A detailed risk assessment and cost comparison, in conjunction with mooring and hydrodynamic analyses of a proposed hybrid DP and contingency mooring system, will be presented in this paper.*

## **INTRODUCTION**

Comprehensive risk assessments are a crucial part of planning for any offshore operation. With moored MODUs in the Gulf of Mexico for example, risk assessments are typically performed for rigs that will be on location anytime during hurricane season. The results of this risk assessment are used in the drilling permit review to determine the duration that the proposed system will be approved by Bureau of Safety and Environmental Enforcement (BSEE). These risk assessments can also be performed for other times of the year to identify the major risk events, but the probability of failure is usually very low outside of hurricane season, so the risk is low. The return period of the mooring system is determined by a limit state

analysis and is used in conjunction with site-specific historical hurricane data to determine the probability of experiencing a mooring line failure. The top risk events are identified by proximity and size (probability of interaction or collision) of surrounding infrastructure along with monetary value (consequence) of temporary damage and loss of production, or long term damage and loss of production. Both surface and subsea infrastructure within a given distance is considered in the risk assessment including platforms, pipelines, well heads, and archeological or environmentally protected sites. The risk to surrounding surface infrastructure can only be mitigated by decreasing the probability of a station-keeping failure. This is achieved by increasing the return period of the mooring system through component sizing and performance optimization. For

# **PREDICTIVE MODEL FOR DRAG EMBEDMENT ANCHOR PERFORMANCE IN CLAY SEABED**

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## *ABSTRACT*

*Predicting the performance of a drag embedment anchor (DEA) in a clay seabed requires: (1) prediction of anchor embedment depth as a function of drag distance, and (2) prediction of load capacity for any given embedment depth. Anchor pullout capacity is influenced by a number of variables including anchor size and configuration, the type and dimensions of the mooring line, properties of the seabed, and details of the anchor installation procedure. A simple model for DEA performance has been developed at Texas A&M University which predicts anchor embedment and capacity in terms of the above-mentioned variables. Recent laboratory model tests that were undertaken to validate the predictive model are discussed in this paper. The paper also presents the results of a parametric study undertaken to assess the influence of anchor/mooring system characteristics and seabed properties on anchor load capacity.*

## **INTRODUCTION**

Drag embedment anchors (DEAs) are an attractive option for moorings in deep waters due to their relatively low installation cost and high holding capacity even in soft clays. Historically they have been used to provide temporary mooring solutions for ships and mobile offshore drilling units. However, their relatively light weight and low installation costs make them particularly appealing for mooring alternative energy systems such as current, wave, and offshore wind power. When considering anchor efficiency in terms of the ratio of load capacity to anchor weight, plate anchors generally possess an inherent advantage as their mass is concentrated deep in the seabed where soil resistance is greatest. This is in contrast to the various pile and caisson anchors for which much of the anchor mass is distributed in soft shallow seabed sediments that contribute little to load capacity.

From the standpoint of predicting the load capacity of an anchor in a given seabed sediment profile, two issues arise. The first is a need for predicting the embedment depth (trajectory) of the anchor during dragging. The strength of most seabed sediments increases with increasing depth. Since anchor load capacity scales directly to strength, reliable prediction

of the anchor depth and soil strength is essential to predicting load capacity. The second issue in predicting anchor load capacity is relating soil strength to load capacity. As noted above, load capacity increases in direct proportion to soil strength. However, the situation is somewhat more complicated than simply determining the appropriate scaling factor (referred to as a bearing factor in soil mechanics terminology), due to the fact that the mooring load is not applied directly to the anchor; rather, the mooring load is transmitted to the anchor through a cable or chain. Thus, the anchor is free to rotate during loading. Since anchor load capacity depends on the orientation of the anchor relative to the chain, any predictive model for load capacity must consider the kinematic characteristics of the anchor - i.e., how it rotates under arbitrary load conditions - as well as its load capacity characteristics. Aubeny and Chi (2010) present an analytical framework for analyzing both anchor capacity and trajectory, where they show that anchor trajectory during embedment and its load capacity characteristics are inter-related; i.e., the bearing factor of the anchor influences how deeply it dives during embedment. The Aubeny-Chi model provides the basis for much of what is discussed in this paper.

DEAs typically have relatively complex

# **DRY TREE PAIRED-COLUMN SEMISUBMERSIBLE PLATFORM FOR ULTRA-DEEPWATER OFFSHORE BRAZIL**

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## **ABSTRACT**

*Mega oil and gas reservoirs have been discovered in deep and ultra-deep offshore Brazil. These Pre-Salt discoveries are remotely located at water depths ranging from 2200m (~7,200 ft) to 2600 m (~8,500 ft). Offshore Brazil has unique metocean conditions with long swell periods which present challenges on floating platforms such as Spars and Semis. In addition, the remoteness of location and the associated high cost of vessel mobilization add further pressure on economics and risk. Quayside integration is thus a desired feature of the hull concept in order to eliminate offshore mating and the associated risk to cost and schedule.*

*To explore these pre-salt complicated ultra-deepwater reservoirs usually require large drilling rig and drilling variable payload which result in very large topsides in both size and weight. Spars and TLPs are the only two proven dry tree hull forms in deep and ultra-deep waters in the GOM. However the TLP becomes cost prohibitive if the water depth is beyond 1,524 m (5,000 ft). For large payload systems requiring a large drilling rig, a suitable Spar size creates a challenge for transportation and installation. The semi-submersible hull form is known to offer advantages over Spars such as larger deck space and quayside integration which are essential to reducing offshore commissioning time and risk as well as cost and schedule.*

*Maturation of the dry tree semi-submersible solution in GoM ultra-deepwater (2,400m) had been undertaken by RPSEA and dry tree Paired Column Semisubmersible (PC Semi) platform, developed by Houston Offshore Engineering, was selected by the RPSEA committee in 2009. Extensive wind tunnel tests and wave basin model tests including 1,000-year central GoM hurricanes were successfully completed in 2010. PC Semi hull configuration, TTR stroke, the analytical results and simulation tools had been fully validated.*

*This paper presents validation analysis results of a dry tree PC semi developed with conventional RAM style tensioners, in 2,400m ultra-deepwater of Offshore Brazil Pre-Salt carrying same topsides payloads as RPSEA. The validation analysis was performed by the correlated analysis tools and established analysis procedures. The design efficiencies including payload, steel weight and production efficiencies of PC Semis for BPS and central GoM are addressed and discussed. Highly efficient PC Semi for BPS has been developed, validated and became "market ready".*

## **1. INTRODUCTION**

With the significantly increasing demand on the oil and gas supply, trends of explorations are moving to explore either the challenged and complicated ultra-deepwater reservoirs in Gulf of Mexico (GoM) or remote areas like Offshore Brazil Pre-Salt (BPS) and

offshore Western Australia (WA). These reservoirs usually require large drilling rig and drilling variable payload which result in very large topsides in both size and weight. Spars and TLPs are the only two proven dry tree hull forms in water depths below 1524 m (5,000 ft) in the GOM. However the TLP becomes cost prohibitive if the water depth is beyond 1524 m (5000

# **OFFLOADING AVAILABILITY ANALYSIS FOR SIDE-BY-SIDE FLNG AND LNGC**

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## *ABSTRACT*

*Traditional LNG offloading arms technologies have been used for LNG transfers in open waters, while hose-based technologies for both side-by-side transfers in calm seas and tandem transfers in rough sea conditions are nearing maturity. However, the offloading arms are not fully utilized for side-by-side arrangement since they have a limited allowable motion envelope and there are not adequate numbers of model test validations. Thus, the proper selection of offloading system and methodology will minimize the capital and operational cost involved.*

*The hydrodynamic interactions between FLNG and LNGC vessels for side-by-side arrangement are strongly coupled resulting in high relative motions. These motions play a significant role in evaluating the availability for a successful offloading operation for a given metocean criteria. Thus, offloading availability and reliability remain highly uncertain.*

*In addition, the viscous roll damping has an obvious effect on both the roll and sway motion responses for LNGC since they are coupled. The heave and roll motions of LNGC are influenced by the roll motion of FLNG which indicate the hydrodynamics coupling between the two vessels. Finally, the single amplitude roll motion for the LNGC controls the offloading availability more than the relative lateral motion and combined lateral and vertical motions between the vessels.*

*The main objective of this paper is to present a new approach for the evaluation of the offloading availability for a given metocean criteria based on the calculated relative motion responses for the side-by-side FLNG and LNGC. In addition, the effect of lateral distance between the vessels on both the hydrodynamic interactions and the offloading availability is further investigated.*

## **1. INTRODUCTION**

Offloading between a FLNG (Floating Liquefied Natural Gas) and LNGC (Liquefied Natural Gas Carrier) in side-by-side arrangement is one of the most risky. Obviously, two tankers operating in such close proximity of each other form cause for a potential collision. Therefore, good understanding of a safe and successful offloading system is paramount for the offloading operations. Precise procedures for the offloading operation further promote the safety and well-being of the FLNG offloading and crew.

The availability of offloading is defined as the conditional probability of the ability to carry out offloading operations under at any arbitrary moment in time and under given metocean criteria. The safety and availability of offshore LNG (Liquefied Natural Gas)

offloading operation is governed by several parameters such as: the performance of the assisting tugs, metocean data, mooring line and fender's size, loading arm design and operational envelop, emergency conditions, LNGC maneuverability, and tugboats and mooring master competency and the amount of specialist training [1]. The mooring line loads, fender loads and relative motions between the two vessels need to be calculated for a large number of wind, wave and current sea state conditions [2].

Hyeonsu et al [3] calculated the availability of side-by-side LNG and FPSO arrangement by calculating the dynamic loads acting on side-by-side mooring system based on mooring analysis results using commercial mooring analysis software.

In this work, the availability for offloading operation will be evaluated based on a given arbitrary

# **COUPLED DYNAMIC ANALYSIS OF A FLOATING OFFSHORE WIND TURBINE**

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## *ABSTRACT*

*Floating offshore wind turbines may become a vital choice for harnessing wind power in relatively deep water. Since the turbine may interact with the supporting floating hull, a coupled dynamic analysis is required to understand and quantify the interactions between the wind turbine, floating hull and its mooring system for the design. A numerical code, known as COUPLE, has been extended to collaborate with FAST for the simulation of the dynamic interaction. COUPLE was originally developed for the computation of the interaction between a floating structure and its mooring/tendon/riser system in time domain. FAST was developed by the National Renewable Energy Laboratory (NREL) for computing the wind loads on a wind turbine. A 5MW wind turbine installed on the top of a classical Spar (Hywind-OC3 Spar) is employed to demonstrate the simulation. The numerical results derived in this study may provide crucial information for the design of a floating wind turbine in the future.*

## **INTRODUCTION**

Offshore floating wind turbines have a number of advantages over their land based or offshore fixed counterparts. They do not use land and are usually far away from the shoreline, and thus having fewer objections raised from the mentality of “not in my back yard” (Nimby). Since relatively away from the shore line, winds there are general stronger and steadier than those over land and even near shorelines. In certain cases, they can be extremely valuable in providing power to special industrial power consumption in water far away from land, such as floating LNG terminals and ocean mining activities.

Since offshore wind farms are usually deployed far away from the shoreline, the water there is likely 100 –

200 m deep or even more, which requires the adaption of floating platforms for installing wind turbines because of cost effectiveness. Floating platforms have been developed and deployed by the offshore industry to produce oil and gas in deep water for more than two decades. Profound knowledge gained from the offshore industry applications is now applied to the development of floating wind turbines. Three kinds of floating platforms, namely tension leg platform (TLP), Spar and semi-submersible platform, have been considered for installing wind turbines. Hywind floating turbine was deployed in Norwegian water and its supporting platform was designed based on the concept of Spar (Svenvold, 2009). Related research was conducted on dynamic interactions between a wind turbines and its supporting floating structure. Shim (2007), and Bae, et

# NUMERICAL AND EXPERIMENTAL STUDIES OF OSCILLATING FLOW AROUND A CYLINDER

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## ABSTRACT

*This paper presents results predicted by three different RANS models:  $k$ -epsilon RNG,  $k$ -omega SST and Reynolds Stress for uniform and oscillating flows around a circular cylinder. First the models are applied to a uniform inflow case at  $Re=2,000$ , and the predicted Strouhal number, drag and lift coefficients are compared with experimental measurements of a reference paper in order to validate the proposed methodology and to test the three turbulence models. The models are then applied to the case of oscillating flow at  $KC=9$  and  $Re=2,000$ , and the effects of turbulence model and grid size on the results are investigated. Then, in the case of oscillating flow, the vortex patterns from the numerical simulations and from a flume test conducted in the Fluids & Hydraulics lab at UT Austin, are presented. The results predicted by the Reynolds Stress model using two different meshes are also compared. By changing the velocity magnitude of the oscillating inflow, the Reynolds Stress model is then applied to conduct a parametric study for a wide range of Reynolds and  $KC$  numbers. The in-line forces on the cylinder, predicted by the RANS model, in the case of oscillating flow, are finally compared with those from Morison equation, using the experimental determined values for the drag and inertial coefficients by Sarpkaya (1985).*

## INTRODUCTION

The safety of submarine cylindrical structures has been of increasing importance along with the boom of offshore industry over the last two decades. In the harsh ocean environment, the elements of these structures (e.g. risers, tendons, structural elements) as well as their mooring lines are subject to various loads caused by ocean currents, waves, icebergs, and earthquakes, of which the forces of wave or oscillatory flows are of great concern, because they can induce significant vibration and severely impair the strength of structures.

The 2-D unbounded oscillatory flow around a circular cylinder (with smooth surface) is governed by the Reynolds number ( $Re = U_m D / \nu$ ) and Keulegan-Carpenter number ( $KC = U_m T / D$ ), where  $U_m$  is the velocity amplitude,  $T$  is the period of oscillation, and  $D$  is the cylinder diameter.

Oscillatory flow around a circular cylinder has

been investigated by a large number of researchers (Keulegan and Carpenter 1958; Sarpkaya 1976a, 1976b, 1976c, 1977). Stokes (1851) first decomposed the force acting on a subject oscillating in the fluid into two components: an inertial force and a drag force. Morison et al. (1950) conducted experimental studies on the forces on piles induced by progressive waves and proposed the semi-empirical Morison equation to calculate the in-line forces. The Morison equation is still used in assessing forces on structural elements of offshore platforms today:

$$F = \rho C_m V \frac{du}{dt} + \frac{1}{2} \rho C_d A u |u|$$

The coefficient of inertial force  $C_m$  and the coefficient of drag force  $C_d$  are determined from experimental data. Sarpkaya (1986) conducted a thorough set of experiments to measure these two coefficients at low  $KC$  numbers ranging from 0.4 to 20.

# **A STUDY OF FLOATOVER INSTALLATION ONTO JACKET WITH TWO BARGES**

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## *ABSTRACT*

*Floatover is a new installation method of modules, which has become more and more common in recent years. Generally, installing integrated topside onto a jacket uses a single barge. However, it can also use a catamaran or a couple of installation barges, which has several crucial advantages. This paper investigated floatover installation process on a jacket with numerical and experimental analysis. Numerical analysis in both frequency and time domain were carried out for typical configurations during floatover operation. The challenges of numerical simulation are multi-body hydrodynamics and viscous damping chose. The calculation tools are WAMIT for frequency domain analysis, which can calculate the first and second order wave loads and global motions of multi-body, and SIMO for time domain analysis, which involves viscous damping, multi-body hydrodynamic interaction, and simulation of impact force. Corresponding model tests were also performed in the Deepwater Offshore Basin in the State Key Lab of Ocean Engineering in Shanghai Jiao Tong University. Comparison between numerical and experimental results shows that the response amplitude operator and time series agree quite well. In this installation configuration, the barges and topside have favorable hydrodynamic behaviors in considered sea state, and the loads of equipments are allowable. It can be concluded this two barges floatover concept is feasible.*

## **INTRODUCTIONS**

Topside installation of offshore platform is always a great challenge for offshore operation, particularly in open waters. Conventionally, the topside has been installed onto the jacket by crane barge with lifting method, in which the topside can be constructed as several modular parts onshore and assembled during offshore installation, for schedule and cost advantages. Even the topside could be constructed as one large integrated module to install, only if it has a super heavy-lift crane barge. However, the increasing weight of topside and high costs for crane barges has led designers to consider the float-over method as an alternative. Floatover installation is a method which can transfer the topside of an offshore oil platform from a transport barge onto the support structure directly through barge ballasting<sup>[1]</sup>.

Generally, the floatover operation may be separated into four primary procedures as shown in Fig.1<sup>[2]</sup>. The first procedure involves deck transportation from the fabrication site to the offshore support structure after constructed and debugged onshore. The second procedure involves docking the transport barge to the offshore structure. This procedure includes steps of barge slot entry, in which the surge and sway motions should be suppressed in order to facilitate next installation procedure. The third procedure is transfer the topside load from barge to substructure, in which compensation for unsuppressed relative motions and the absorption of environmental forces from the point of initial contact through complete mating are executed. The fourth and final procedure involves separation of the barge from the deck after load transfer and then removal of the barge from the mating slot.

# HYDRODYNAMIC OPTIMIZATION OF MARINE CURRENT TURBINES

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## ABSTRACT

*This paper describes the use of a lifting line model in order to determine the optimum circulation distribution on a marine turbine's blades, based solely on their geometrical and operational parameters and on the characteristics of the inflow. A linear solution is proposed first, which includes the effects of viscous drag through a drag-to-lift ratio. The model is then extended to include higher order terms in the case of inviscid flow. The maximum efficiencies for both models are presented as a function of the turbine's tip speed ratio and the number of blades.*

## NOMENCLATURE

Flow parameters:

$V$	Current speed
$\omega r$	Rotational speed
$\phi$	Blade pitch angle
$V^*$	Total inflow velocity relative to the turbine sections (it includes the induced velocities)
	$\left( V^* = \sqrt{(V - u_a^*)^2 + (\omega r + u_t^*)^2} \right)$
$u_a^*$	Induced axial velocity
$u_t^*$	Induced tangential velocity
$\beta$	Pitch angle of the undisturbed inflow, relative to the blade sections
	$\left( \tan \beta(r) = \frac{V}{\omega \cdot r} \right)$
$\beta_i$	Pitch angle of the total inflow $V^*$ relative to the blade sections
	$\left( \tan \beta_i(r) = \frac{V - u_a^*}{\omega \cdot r + u_t^*} \right)$
$D$	Drag on a blade section (in the direction of $V^*$ )
$L$	Lift on a blade section (normal to the direction of $V^*$ )
$\Gamma$	Circulation around a blade section

Turbine characteristics:

$c$	Chord length
$C_D$	Sectional drag coefficient
$\kappa$	Drag-to-lift ratio
$Z$	Number of blades
$R$	Radius of the turbine
$r_h$	Hub radius

## INTRODUCTION

In the past decade, great attention has been given worldwide to the study of unconventional forms of hydroenergy, from tidal or ocean current power to wave power and river currents power. Research has recently focused on the development of hydrokinetic marine turbines, an emissions-free, low-impact and renewable alternative to larger hydropower schemes. Numerous projects have so far been proposed, and pilot turbines are currently being tested, but this remains an expensive technology that often requires subsidies to be feasible. Furthermore, very few design tools have been created and made public, thus forcing engineers to opt for more traditional alternatives with high environmental impact. The authors seek in consequence to develop and improve upon several optimization tools that will allow the design of efficient hydrokinetic turbines.

# **DRIFT-OFF AND DRIVE-OFF ASSESSMENT OF A DYNAMICALLY POSITIONED DRILLSHIP**

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**ABS**

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## **ABSTRACT**

*It is important that a floating drilling unit is able to disconnect from the wellhead in a timely manner during a loss of position to minimize risk to personnel, the environment, and equipment. For most dynamically positioned (DP) vessels, the concept of watch circles has been used for that purpose. The watch circles define when to initiate disconnecting action. Typical watch circles are referred to as green, yellow and red circles. When a vessel is in the yellow circle, the operation should be halted, while in the red circle, the Emergency Disconnect System (EDS) should be initiated.*

*Drift-off and drive-off assessment can be utilized in the determination of the green, yellow and red watch circles. Drift-off is a scenario of the vessel drifting away after a loss of thruster power, while drive-off is of the vessel being pushed away by excessive thruster force.*

*Drift-off and drive-off are functions of a vessel's characteristics and the prevailing environmental conditions. This paper presents the study on the drift-off and drive-off scenarios of a DP drillship under different environmental conditions. The vessel's excursion as a function of time is simulated using a time-domain simulation program aNySIM. The comparison of drift-off and drive-off speed under different environmental conditions will be made. The effect of environmental conditions on the determination of watch circles is assessed.*

## **1. INTRODUCTION**

A significant number of drillships have been built or ordered in recent years in response to increased deepwater offshore activities, advantages of their mobility and large load capacities. This trend can be illustrated by the number of drillships classed by ABS (Figure 1).

Modern drillships are built with a Dynamic Positioning (DP) system. Over all, the number of DP floating units has increased almost sevenfold in the last ten years.

Operational safety of DP units has been subject to continual improvement over the years. However, the expansion in the application of DP systems both in numbers and in the range of activities, can present operational challenges. The demand for and availability of high quality experienced personnel,

including in the areas of design, fabrication, inspection and operation can also be considered a central factor in the safe operation of DP vessels. Training, regulation, guidance documentation may provide improvement in this area.

It is important that a floating drilling unit is able to disconnect from the wellhead in a timely manner during a loss of position to minimize risk to personnel, the environment, and equipment. For most dynamically positioned (DP) vessels, the concept of watch circles has been used for that purpose. The watch circles define when to initiate disconnecting action. Typical watch circles include green, yellow and red circles. When a vessel reaches the yellow circle, the operation should be halted, and when entering the red circle, the Emergency Disconnect System (EDS) should be initiated. Figure 2 depicts a typical watch circle patterns.

# **THE ROLE OF SNAME OC 7 IN THE DEVELOPMENT OF THE ISO FOR SITE ASSESSMENT OF JACK-UPS**

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## **ABSTRACT**

*The first edition of T&R Bulletin 5-5A, "Recommended Practice for Site Specific Assessment of Mobile Jack-Up Units" [ref. 1] was published by SNAME in May 1994 and was launched at a meeting during OTC that year. The document had been developed by representatives of all sectors of the industry during the previous six years, funded by a Joint Industry Project, and SNAME was approached to publish the document in order to widely disseminate it to industry. Offshore Committee 7 (OC7) was formed to both maintain the document, and to integrate new technology and revisions as they became available. The publication, however, was controversial as many felt the document was too conservative and had not been properly benchmarked, so around the same time, drilling contractors began working under the auspices of IADC to determine what could be done to improve both the usability and applicability of the document. The IADC Jack-Up Committee was born out of these efforts, and over the past 15 years, has funded many projects resulting in new knowledge, understanding and significant improvements in the calculation methodologies.*

*In 1996, ISO Work Group 7 (WG7), part of Sub Committee 7, was formed and mandated by the parent ISO Technical Committee for Offshore Structures, ISO/TC67, to develop the jack-up site assessment standard using T&R 5-5A as the basis. A long period of development followed with new technology being funneled through the OC7 Revisions Sub-Committee to T&R 5-5A. Most of the new material went into the T&R Bulletin, and was later adopted into the developing ISO document, but as the ISO become more complete, material tended to bypass 5-5A. This did not negate the role of the Revisions Sub-Committee: one of the requirements for new material for inclusion in 5-5A was that it be presented in "Document Ready" wording. While new material still may have needed some editing to get into ISO-Speak, the "Document Ready" requirement saved substantial time. In addition, during the development of the ISO document, the only formally published document was T&R 5-5A, during which time OC7 played a vital role in keeping the site assessment document current.*

*This paper sets out the role played by SNAME OC7 in the development of the ISO 19905-1 and 19905-2 [ref. 2 & 3], and shows the value of having SNAME, an internationally recognized body, maintain the document while the ISO was being developed. The paper also discusses the role of industry in the future maintenance of the documents, and the necessity of encouraging new participants into the relevant committees.*

# **A PACIFIC PARTNERSHIP – PAST, PRESENT AND FUTURE COOPERATION BETWEEN SNAME AND SHANGHAI SNAME**

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## *ABSTRACT*

*There has been a growing cooperation between the professional societies representing naval architects, marine and ocean engineers. One such cooperation is between the Society of Naval Architects and Marine Engineers, SNAME, headquartered in the US and the Shanghai Society of Naval Architects and Marine Engineers, S-SNAME, based in Shanghai.*

*There are many shared issues between these two professional societies, both technically and geographically, with strong interest in the offshore sector and developments in Asia Pacific in general*

*This paper will describe cooperative efforts between SNAME and S-SNAME with particular reference to the recent past and present actions, but will focus on the potential for future activities of mutual benefit to the members of both Societies.*

## **INTRODUCTION – THE IMPORTANCE OF NAVAL ARCHITECTS, MARINE AND OCEAN ENGINEERS:**

Unlike the conventional wisdom of the day we, as naval architects, marine and ocean engineers, recognize that humans are not separated by the world's oceans but are in fact connected by them.

I would go further and postulate that since the planet we live on is largely covered by water and since humankind exists and thrives because of our capability to successfully harness the resources which the world provides, those who are trained to create solutions for issues associated with the ocean, *naval architects*, must, a priori, be amongst the most important class of persons on our little globe.

Some facts and figures to support this assertion:

- Approximately 70% of the earth's surface is covered by water
- Over 95% of the world's inter-continental trade moves by sea
- A significant portion of the world's food comes from the sea ~ 16% of world animal protein consumption by humans comes from fish.
- Around 40% of the world's population lives within 100 km of the coasts and this percentage is rising rapidly
- A large part of the world's oil lies the under the sea – in the US there are ~21 billion barrels of proven reserves of conventional oil (including 4 billion



**Figure 1 – Planet Earth or Planet Ocean**