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DYNAMIC POSITIONING CONFERENCE

October 13-14, 2009

Risk

Onboard Tools for Planning and Optimizing SIMOPS

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ABSTRACT

Many latest-generation dynamically positioned (DP) drilling rigs are equipped with dual activity derricks and/or subsea cranes capable of deploying subsea equipment, such as trees and manifolds. This allows the performance of simultaneous operations (SIMOPS), such as drilling through the drilling riser while simultaneously running strings of casing or deploying subsea equipment. This can result in significant reductions in the time taken to drill wells with associated cost savings.

Careful planning of SIMOPS is required to eliminate the risk of clashing between equipment and the drilling riser through the water column, and also to optimize parameters such as vessel position and heading for specific operations. This paper describes an onboard simulation tool designed for use on DP drilling rigs that can be used to plan SIMOPS. The tool has been deployed on a number of deep water projects in the Gulf of Mexico. The simulator can acquire input data from relevant instrumentation and vessel systems, such as ADCP current meters and the DP system.

The simulator uses a fully-coupled 3D finite element (FE) model of the riser system, thereby allowing accurate determination of the riser response to current loading. The tool allows onboard personnel to check/confirm the feasibility of various SIMOPS using either prevailing or forecast metocean conditions or to optimize procedures to minimize risks. The key features of the onboard simulator are discussed, with particular emphasis on the potential to optimize operations. The benefits of the system in planning SIMOPS are illustrated by means of a case-study.

INTRODUCTION

As exploration and development drilling moves into deeper waters and more harsh environments, the challenges faced by drilling contractors in operating in a safe and cost-effective manner have steadily increased. This, coupled with the historically high oil price that prevailed until recently, has driven the demand for high capability sixth-generation drilling rigs. At the start of 2009, a record number of units were either under construction or on order, with a significant number of these units designed for deepwater operations and equipped with DP capability.

The ability of these units to command very high day rates (in excess of $500,000 per day in many instances) is due largely to their ability to drill in deep waters and challenging environmental conditions. With day rates so high, there is substantial pressure to maximize operational efficiency. One approach to achieving this has been to design vessels that can carry out simultaneous drilling-related operations, or SIMOPS. Vessels with SIMOPS capability typically have a dual derrick drilling system in which the main drill center is augmented with an auxiliary drilling center (see, for example, Figure 1). They may also be equipped with high-capacity subsea cranes and/or winches that can be used to deploy subsea equipment.

Figure 1. Sixth generation drillship equipped with a dual derrick

This equipment allows a range of operations to be performed in parallel. For example, strings of casing can be run from the auxiliary drill center while the drilling riser is deployed (and drilling is potentially being undertaken) from the main drill center. When the appropriate part of the well is drilled, the casing is ready to be installed immediately, without having to retrieve the riser. This can save significant amounts of rig time (and therefore cost), especially in deep water where retrieving the riser can be a time-consuming exercise. (Note that in the offshore industry the term SIMOPS has a general meaning of any two operations carried out simultaneously, however in the context of this paper the term is taken to refer specifically to drilling-related operations being carried out in parallel.)

In a development drilling scenario, the ability to install significant pieces of subsea infrastructure (such as trees, manifolds, jumpers, etc.) while the drilling riser remains deployed can also save significant amounts of rig time. Typically, large pieces of infrastructure such as manifolds are deployed on lengths of drillstring from the auxiliary drill center, while smaller equipment may be deployed using a subsea crane or winch.

Carrying out SIMOPS, however, is a complex task that requires significant coordination between various operational personnel onboard the rig and brings with it a significant additional level of risk. Specifically, ocean current loading on the drilling riser and on casing or subsea equipment that's being deployed through the water column can cause the equipment to come into close proximity with, or even contact, the drilling riser. This is an unacceptable hazard that could lead to damage to subsea equipment or to the drilling riser itself with serious implications. Managing the vessel heading becomes critical to ensuring that the risk of contact between the riser and casing or subsea equipment is minimized.

Another important issue when deploying large pieces of subsea infrastructure is managing the vessel position. The horizontal distance between the subsea equipment as it nears the seabed and the vessel center can be quite significant. This is especially the case in deep water, high current locations (such as the Gulf of Mexico and offshore Brazil) due to the lateral loading on the equipment and the pipe or winch cable used to deploy the equipment through the water column. For this reason, careful positioning of the vessel by the DP Operator is required to ensure that the subsea equipment is landed at its design location. This must be done without compromising the safety of other operations.

It is clear that a significant level of planning is required before carrying out any SIMOPS in order to mitigate risk and ensure the success of the operation. A certain level of planning can be carried out in the office in advance of carrying out operations using design environmental conditions. These design environmental conditions are normally statistical representations of the long term metocean conditions at a particular location; they incorporate a level of conservatism in order to represent “worst case” scenarios. Because of this, the purpose of upfront planning is mainly to determine the limiting metocean conditions in which certain operations can be performed.

When on-site, however, the prevailing metocean conditions may be somewhat different to those used at the design and planning stage. This, coupled with the nature of SIMOPS (the safety of which can be highly dependent on, for example, the direction of ocean current loading), drives the requirement to be able to simulate and plan SIMOPS onboard the vessel using the prevailing metocean conditions. The feasibility of doing this is increased by the fact that many modern drilling rigs are equipped with Acoustic Doppler Current Profiler (ADCP) systems that can provide a measure of the ocean current profile for all or part of the water column, thereby allowing more accurate determination of the ocean current loading on both the drilling riser and casing or subsea equipment. Even in the absence of ADCP systems, most modern rigs feature upper and lower riser angle sensors that can be used to estimate the ocean current loading on the riser, and most also have hydroacoustic positioning systems that can be used to provide an indication of the position of subsea equipment during deployment.

Thus, on onboard simulator can provide the capability to establish the feasibility of carrying out SIMOPS in the prevailing (or forecast) metocean conditions and can also be used to optimize the operation with a view to minimizing risk.

DESCRIPTION OF ONBOARD TOOL

The software tool described in this paper is a development of an onboard drift-off simulator that is used to provide confirmation of alert offsets for DP drilling rigs during connected (drilling and non-drilling) operations. The operation of this tool is described in detail in [1]. This tool can also be used to plan riser deployment/retrieval and drift-running operations; its operation in this regard is described in more detail in [2].

As many of the capabilities required to simulate vessel drift-off and riser deployment/retrieval have significant elements in common with the capabilities to simulate SIMOPS (such as onboard metocean data input, riser analysis, etc.) it was considered a logical step to extend the capabilities of the existing tool to incorporate SIMOPS simulation capabilities. This approach had the added benefit of reducing the level of training required for onboard personnel, as they were already familiar with many aspects of the tool.

SIMOPS Model

Fundamental to the operation of the tool is a finite element (FE) model of the drilling riser and casing or subsea equipment. This is used to compute the response of the drilling riser and casing or subsea equipment to the ocean current loading during SIMOPS. The FE model is based on a widely-validated non-linear FE software tool [3].The formulation employed uses a 3D hybrid beam-column element with fully coupled axial, bending and torsional degrees of freedom, and incorporates independent interpolation of axial force and torque distributions in each element using penalty functions (this approach gives rise to the use of the term “hybrid” beam-column element). This formulation, which uses an iterative scheme to achieve solution, is discussed further in [4] and [5].

The details of the drilling riser stack-up are entered into the software tool in the drilling contractor’s office on-shore and e-mailed to the drilling rig. These details include all of the structural properties of the drilling riser joints (including joint weights in air and water and joint dimensions) and the list of joints that comprise the riser stack-up.

Similarly, details of any subsea equipment that is to be installed are entered into the software tool on-shore and e-mailed to the drilling rig. These details include the weights and dimensions of subsea equipment (for example, trees, manifolds, jumpers, etc.), design installation coordinates (usually specified in a suitable coordinate system such as UTM) and details of how the equipment is to be installed (auxiliary rig, subsea crane, etc.). Details of drillpipe strings to be used for installation may also be specified along with details of casing strings where appropriate.

Once the relevant data has been e-mailed to the drilling rig, it is loaded into the onboard software. Onboard personnel have only limited facilities for modifying the model, thereby ensuring consistency between the models used to carry out onboard SIMOPS planning and those used to carry out planning on-shore.

Operator Interface

The onboard SIMOPS simulator provides an interface that is designed to be intuitive and familiar. Figure 2 on the following page shows an example of the operator display. The interface provides two graphical views of the operation, which are designed to provide the operator with succinct information regarding the SIMOPS operation.

The main view is a plan view, visible in the left-hand portion of the blue area visible in Figure 2. This view shows an outline of the vessel position and heading (the outline of a semisubmersible drilling rig is visible in Figure 2), along with the location of the wellhead and any subsea infrastructure. Subsea equipment is shown in this view as either a ghost image at the design position (if the equipment has yet to be installed) or as a solid image at the actual installed position if the equipment has actually been installed.

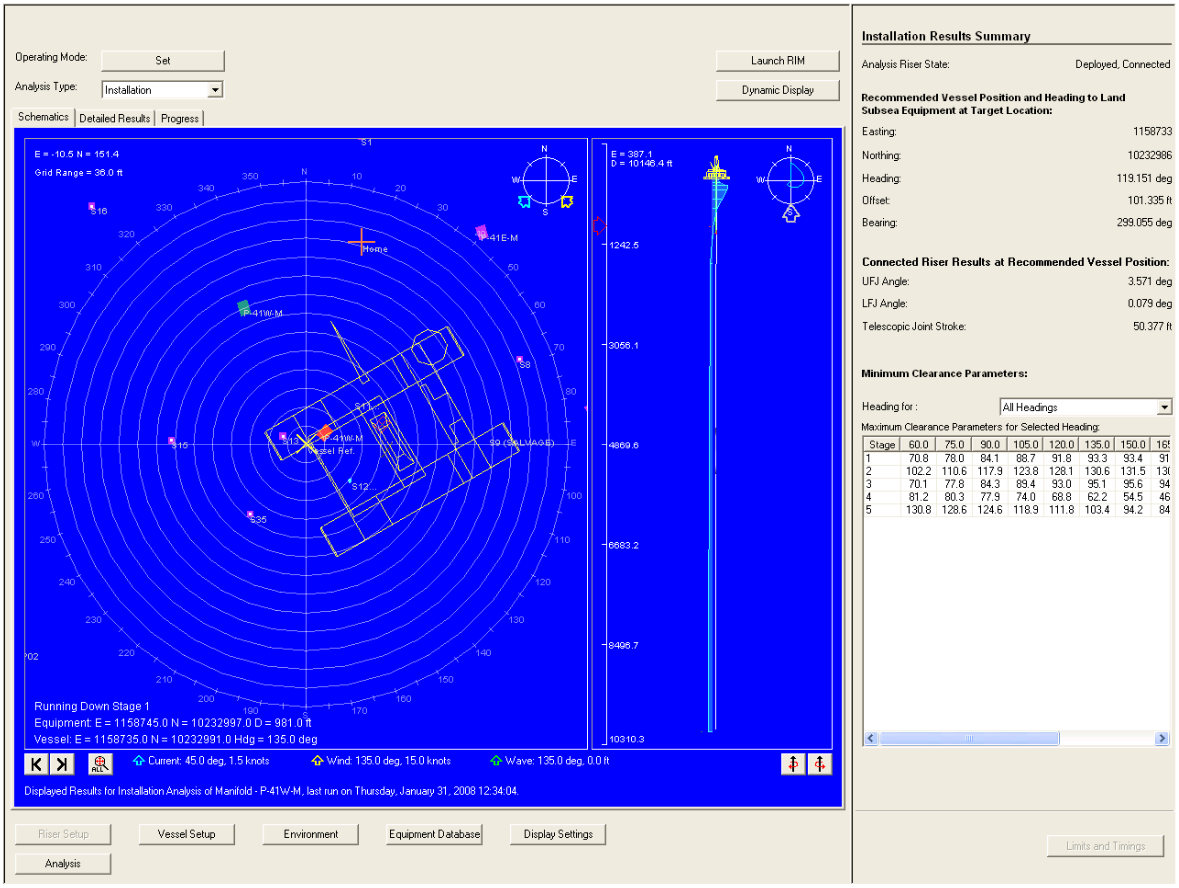

Figure 2. Example of onboard software operator interface

The right-hand part of the blue area visible in Figure 2 shows an elevation view of the operation. This allows the operator to easily identify the stage of the operation that is currently being viewed by highlighting the depth to which casing or equipment has been run. The operator can zoom in/out of both parts of the display to examine areas of interest in greater detail. It is also possible to rotate the viewpoint used for the elevation display.

In addition to the graphical display, key numerical results of simulations are provided in the results panel on the left-hand part of the display. These results include details of the estimated proximity between the drilling riser and subsea equipment or casing as it is deployed through the water column. For simulations of subsea equipment installation, the results also include the recommended vessel position in order to land the equipment at its design location. In addition to the recommended vessel position, the predicted drilling riser upper & lower flex joint angles and telescopic joint stroke at the recommended vessel position are displayed. This allows the DP Operator and the Subsea Engineer to assess the feasibility of continuing to drill if the vessel is moved to the recommended position.

Metocean and Other Data Input

The operator interface provides a system of menus for entering the details of the operation that is to be simulated. Broadly-speaking, the data used in each simulation can be broken down into four categories:

- **Vessel Data**
  - Current/planned vessel heading
  - Current/planned vessel position

- **Riser Data**
  - Riser state (connected or hung-off)
  - Designation of well to which riser is connected (if connected)
  - Riser top tension (if connected)
  - Riser mud weight (if connected)
  - Number of joints deployed (if riser hung-off)
  - Upper and lower flex joint angles

- **Metocean Data**
  - Ocean current profile and direction

- **SIMOPS Operation Details**
  - Nature of operation (installation of subsea equipment or running casing)
  - Details of casing string to be run (if running casing)
  - Drill center to be used for running casing (main or auxiliary center)
  - Details of subsea equipment to be installed (if appropriate)
  - Method of installation (auxiliary drill center, subsea crane or winch)
  - Number of stages to be examined in simulation

Depending on the mode of operation, some of this data may be acquired directly from other onboard vessel systems or it may be specified by the operator. When the system is operating in full “offline” mode, all of the input data is specified by the operator, allowing the operator to look at a range of scenarios in different environmental conditions.

Alternatively, the system can be configured to acquire certain input data from other onboard vessel systems. Vessel position and heading data can be acquired from the DP system (using a standard serial protocol such as NMEA) or from a GPS and gyrocompass; riser top tension can be acquired from the marine riser tensioner system; riser mud weight can be computed from pressure readings obtained from the BOP Mux and riser flex joint angles can be acquired from the Electric Riser Angle monitoring system. Finally, an interface to the ADCP is provided to facilitate acquisition of ocean current profile data.

In scenarios where the system acquires data from other onboard vessel systems, the operator is provided with a facility to overwrite the measured data acquired from the other systems – this feature allows the operator to examine “what if” scenarios, for example “what would happen if the current direction changed or the vessel heading changed”.

Whether the system is operating in full offline mode or not, the operator must specify the details of the simultaneous operation that is being planned. This includes the number of individual stages to be simulated during the operation, which is normally defined in terms of a series of depths (for subsea equipment installation) or lengths of casing deployed. The onboard simulator then performs an analysis of the operation at each specified depth or for each length of casing deployed.

Simulation Procedure

Once all relevant input data has been acquired and/or specified by the operator, the simulation can be performed. Figure 3 below shows a flowchart for a typical SIMOPS simulation.

The software initially generates the finite element model of the drilling riser and subsea equipment or casing based on the input data specified on-shore and transferred to the rig. This operation, including the generation of the FE mesh, is carried out completely automatically – it is not necessary for the operator to specify any FE meshing parameters. A number of FE models are generated – one for each stage of the operation, each one corresponding to a different depth of subsea equipment deployment or a different deployed length of casing.

For each stage of the operation, the simulator initially performs a static analysis in which only gravity, buoyancy and tension loads are applied to each structure. This is referred to in Figure 3 as the "initial static" analysis.

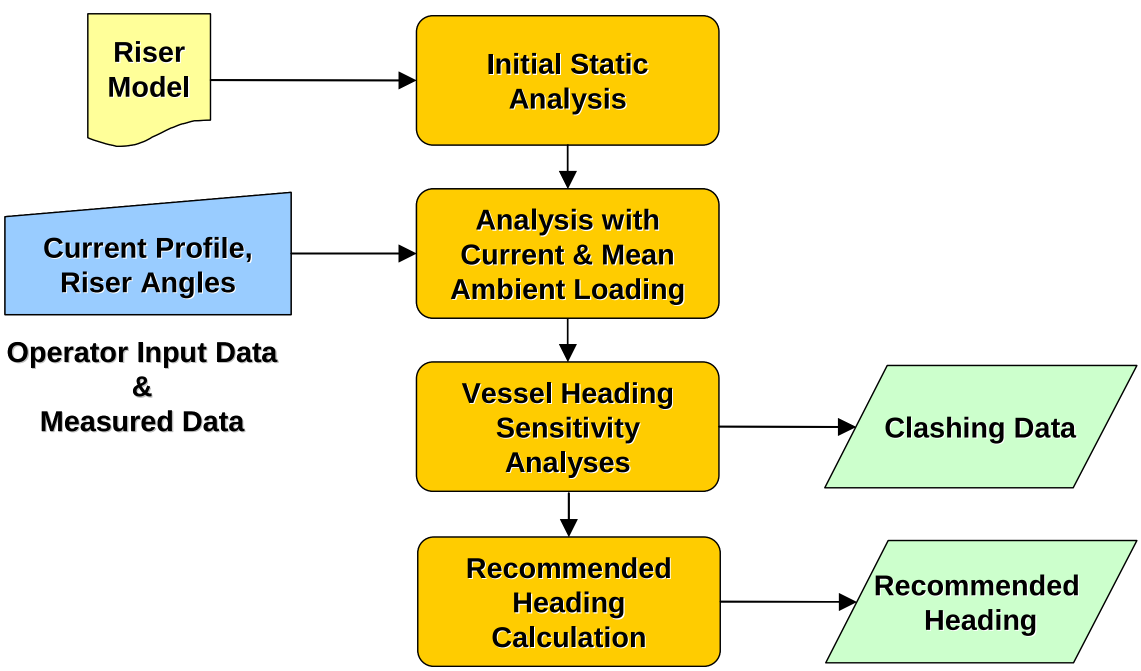

Figure 3. Flowchart for typical SIMOPS simulation

In the next step of the simulation, the measured ocean current profile is applied as a load to the structures. The output of this step is the *predicted* response of the drilling riser and subsea equipment or casing to the ocean current loading. This prediction is based on the estimated drag force coefficients that were specified on-shore along with the other model data. There is some uncertainty associated with these drag force coefficients as in reality they are dependent on the Reynolds number of the flow around the structures and certain other parameters.

To address this uncertainty, the simulator calibrates the loading applied to the model by comparing the measured riser flex joint angles with those predicted by the model. The loading applied to the structure is adjusted until the flex joint angles predicted by the model match the measured values. The resulting calibrated load is applied in all subsequent steps of the simulation.

Once the loading calibration step is complete, the simulator computes the minimum clearance between the subsea equipment or casing and the riser. If this minimum clearance is below a certain (operator-specified) threshold value, the simulator will alert the operator to the potential for clashing to occur. The simulator then performs a sensitivity analysis where the heading of the vessel is changed in fixed increments. For each heading increment, the simulator performs an analysis of the riser and subsea equipment or casing and computes the minimum clearance between the two structures. In this way, the simulator determines how the minimum clearance varies as the vessel heading varies.

The steps described above are repeated for as many steps as the operator has specified when setting up the simulation. For simulations of installing subsea equipment or running casing into a well, the simulator then performs a final step where it computes an estimate of the vessel position required to land the equipment at its design location or land the casing string at the target well. Next, the simulator performs an analysis with the vessel at this recommended position. This is done to determine the potential for clashing and also to determine key drilling riser response parameters, such as upper & lower flex joint angles and telescopic joint stroke at the recommended vessel position. These outputs can be used to assess the feasibility of moving the vessel to the recommended location.

Results for each stage of the simulation are displayed graphically on the operators interface, and the operator can review the results by running through them stage-by-stage. Key numerical results are also displayed and all results are detailed in a comprehensive *simulation report file* that can be printed for future reference.

CASE STUDY – RUNNING CASING

The use of the tool is illustrated by an example simulation of running a string of casing from the auxiliary drill center of a dual derrick drilling rig, while the drilling riser is deployed from the main drill center with the BOP stack landed on a well. Table 1 on the following page summarizes the key aspects of the scenario, while Table 2 lists the input data for the simulation that is specified or acquired onboard the vessel, and the source of this input data. The *Analysis Setup* dialog, which is used by the operator to specify much of this input data, is shown in Figure 4 on Page 10.

Table 1. Key aspects of example casing running scenario

Water depth:	10,000 ft
Vessel type:	Semisubmersible
Simulation of:	Running of 36” x 1” wall thickness casing
Casing run from:	Auxiliary drill center
Riser state:	Deployed from main drill center with BOP landed and latched on well
Spacing between main and auxiliary drill centers:	36 ft
Number of running stages to be analyzed:	10 (1,000 ft depth increments)
Main parameters of interest:	1. Clearance between casing and riser at each depth analyzed 2. Recommended vessel heading at each depth analyzed to maximize clearance between casing and riser

Table 2. Input data and sources for casing running scenario

Input:	**Source:**
Vessel Data:	
Vessel Position and Heading	DP/Rig Position System
Riser Data:	
Top Tension	Riser Tensioner System
Mud Weight	BOP Mux
Telescopic Joint Stroke	Riser Tensioner System
Casing Data:	
Casing Deployment Depths	Operator Specified
Clearance Tolerance with Riser	Operator Specified
Environmental and Riser Response Data:	
Current Profile (Velocity and Heading over Range of Depths)	ADCP
Riser Angle Data	Electric Riser Angle System

Once all input data has been acquired from other vessel systems or specified by the operator, the simulation is carried out using the procedure described in the preceding section. The total simulation time depends on the number of operational stages to be analyzed, however with modern desktop computing power the simulation generally completes in a matter of minutes.

Upon completion, the operator display updates with the results of the simulation. The operator can then view the results from each stage graphically. A prominent warning symbol is shown on the graphical display to indicate if the clearance between the casing and the riser is less than the operator-specified clearance tolerance, which would indicate that clashing is possible. The warning symbol indicates where this may occur and at what stage of the operation.

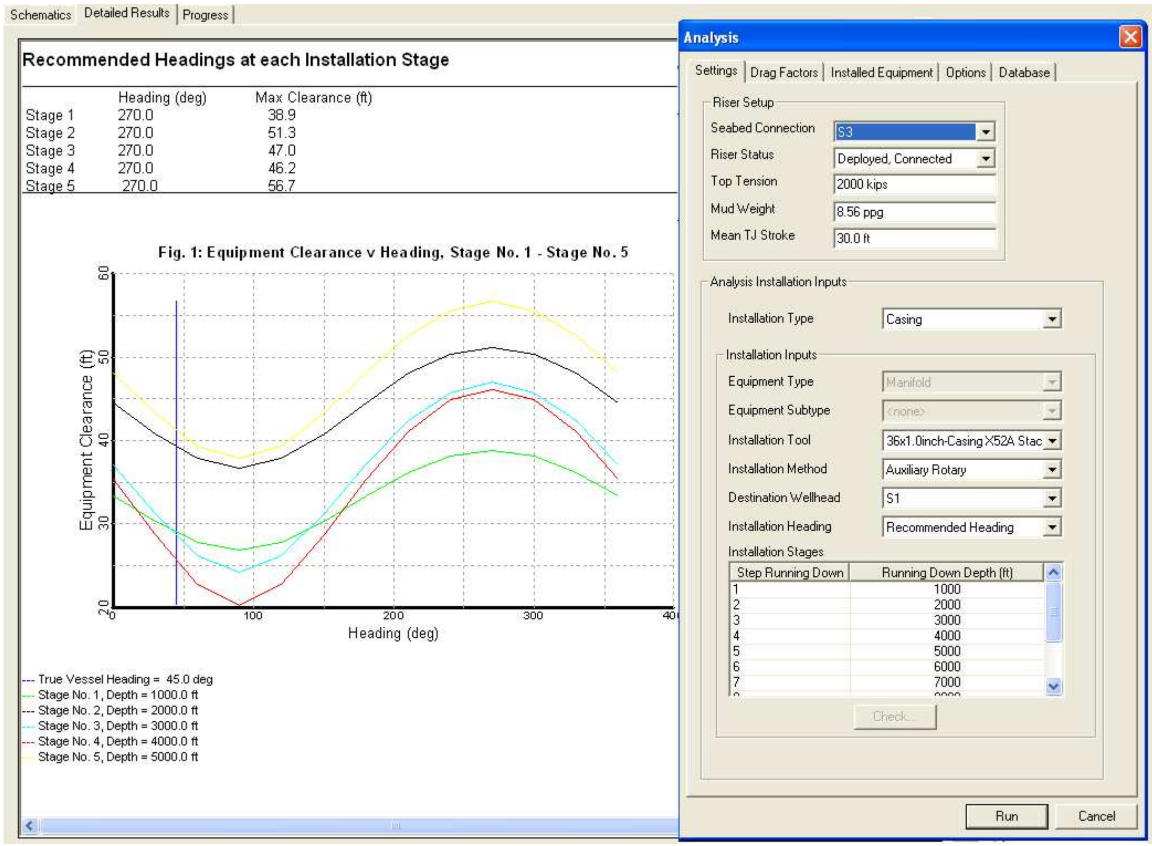

Figure 4. Selected results from casing running example showing how the minimum clearance between the casing and the riser varies with vessel heading. The *Analysis Setup* dialog is shown on the right.

In addition to the graphical display, the operator can view more detailed results from the simulation. An example detailed results display is shown in Figure 4 above. This presents a plot showing how the minimum clearance between the casing and the riser varies with vessel heading. The vertical blue line towards the left end of the plot shows the operator-input or current vessel heading.

It is clear from this plot that the current vessel heading is not optimal in terms of maximizing the clearance between the casing and riser, although the current heading does result in a minimum clearance of approximately 25 ft. If, however, the current vessel heading can be changed from the present 45 degrees to closer to 300 degrees without adversely affecting other operations (or the vessel's station-keeping capability) this will result in significantly enhanced clearance and a reduced risk of clashing. In this way, the simulator supports decision-making that can result in optimizing the operation.

CONCLUSION

An onboard simulator has been developed for use on DP drilling rigs that provides the capability to plan simultaneous drilling-related operations onboard the drilling rig. These operations can be planned onboard using prevailing or forecast metocean conditions, which provides increased confidence in the ability to carry out SIMOPS. The ability to simulate such operations in advance allows identification and minimization of the risks associated with these operations, thereby enhancing the safety of the operations and the integrity of the equipment involved.

Furthermore, the ability to plan operations in the prevailing metocean conditions can reduce the conservatism associated with office-based planning, which must by definition incorporate conservative assumptions as to the nature of the environmental loading. This gives the potential for a reduction in the time spent waiting on weather, with consequent cost savings. The on-board simulator is in use on a number of the latest-generation drilling rigs worldwide and is proving to be a significant aid to planning drilling-related SIMOPS.

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