WHITEPAPER

FLOATOVER ANALYSIS

From modelling to time-domain analysis using Sesam™
Reference to part of this report which may lead to misinterpretation is not permissible.

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<tr>
<th>No.</th>
<th>Date</th>
<th>Reason for Issue</th>
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1 EXECUTIVE SUMMARY

With wider use of the floatover method during deck installation, challenges facing engineers are numerous. Sesam Marine (Sima, Simo and Riflex), state-of-the-art software that is part of the Sesam family, provides a reliable and efficient solution for analysing the procedure of floatover operation in different phases, including standby, entry, mating and exit, etc.

- Compared to a conventional DOS command based tool, the modernized GUI in Sima allows engineers to design and manipulate the models and settings during operations in a user-friendly and interactive way. Models can be verified either from a text file or in graphic view in different phases of the analysis. This will save tremendous time during project analysis.

- Various of objects and methods built in Sima, e.g. docking cone, fenders and bumpers, can help our engineers simulate the whole system as accurately as possible, including some key parts like DSU (Deck Support Unit) and LMU (Leg Mating Unit). This will definitely increase the confidence of operation since far fewer assumptions and approximations have to be made in Sima, compared to other traditional methods.

- In addition to the quasi-static methods that are widely used now, Sima also provides the advanced coupled FE method for mooring systems. This leads to more detailed tension check and other unique checks that may be needed in floatover analysis, such as clearance check between mooring lines and on-bottom pipelines.

- The calculation algorithm is so efficient that the analysis time can be expected to decrease from days to hours, compared to other software tools. In addition, utilization of variable parameters makes parametric design and optimization possible.

- The powerful in-built post-processor can satisfy your engineers’ needs for quick results checks, detailed statistics post-processing, plotting and more.

To summarize, Sesam Marine is an outstanding tool for managing the risks during marine operation analysis.

This white paper aims at documenting the efficiency of Sesam for floatover analysis.
2 INTRODUCTION

Floatover deck installation is becoming increasingly popular and reliable in recent years. The floatover technology uses a variety of floatover systems and lets large platform topsides be installed as a single integrated package without the use of a heavy lift crane vessel. This allows not only the elimination of expensive day-rate derrick barges, minimization of offshore hookup, and maximization of onshore testing and commissioning, but also freedom of equipment layout within the deck compared to modular lifting designs\(^1\).

Floatover installation can be applied for topside installation of both fixed and floating platforms. An 18,000 ton EAP GN topside and a 21,800 ton Lunskoye-A topside had applied floatover installation onto jacket substructure and concrete gravity-based structure respectively\(^2\).

Sesam Marine provides the ability to visualize the operations in 3D and run multiple ‘what-if’ scenarios showing the results of all known factors, including dynamic positioning. It reduces risk significantly for transportation, installation and lifting of fixed and floating structures and installation of subsea equipment.

This white paper aims to provide a reference of the best practice to conduct a floatover analysis with Sesam, including simulations and analysis from modelling and hydrodynamics to non-linear time-domain analysis, result evaluation and reports. Various installation phases, including standby, entry, docking and mating, and exit operations with different critical steps are explained.

A typical workflow in Sesam could be as below.

Though many real project experiences were referred during the preparation of this document, all the data below are for demonstration purpose only and in no circumstance should they be used directly in real projects.

If readers want to learn the best practice from this white paper, please kindly contact our support team via software.support@dnvgl.com. A workshop may be arranged upon request.
The following modules from Sesam were used during the preparation. These could be the basic configuration if our clients want to reproduce the analysis or purchase the software for their projects.

<table>
<thead>
<tr>
<th>Modules</th>
<th>Short Description</th>
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</thead>
<tbody>
<tr>
<td>GeniE with extension for curved geometry</td>
<td>Conceptual panel modelling</td>
</tr>
<tr>
<td>HydroD, Wadam and Postresp</td>
<td>Hydrodynamic analysis in the frequency domain based on the radiation diffraction methodology for large volume structures based on input data prepared from HydroD GUI</td>
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<tr>
<td>Sima, Simo and Riflex</td>
<td>Manage risk of marine operations with visual simulation of calculations</td>
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<tr>
<td></td>
<td>Non-linear time domain simulation of motions and station-keeping behaviour of a complex system of floating vessels and suspended loads. The forces include wind, waves and current</td>
</tr>
<tr>
<td></td>
<td>Non-linear strength analysis of risers and other slender structures</td>
</tr>
</tbody>
</table>
3 MODELLING AND HYDRODYNAMICS

3.1 Panel modelling
GeniE is used to prepare both the panel finite element model (FEM) for hydrodynamic analysis, as well as the geometry files used later in Sima for demonstration purpose. Regarding how to use GeniE, please refer to DNV GL - Software course: SE-03 Hull modelling for hydrodynamic analysis - Introductory training. Below is a typical T-shape barge FEM model (half).

Sima supports import of several types of geometry files for viewing purposes. GeniE can export *.obj files for use in Sima. Our users can control the colours or the transparency of different parts (panels or beams) of the model by modifying the parameters in View Option.

When saving the .obj file, there will be an extra *.mtl file saved for each *.obj file. It includes the colour information. Users need to put them in the same folder to include colour information. An example is shown below.

3.2 Hydrodynamic calculation
The purpose of hydrodynamic calculation is to get hydrodynamic coefficients of the barge, such as added mass and potential damping coefficients, first order wave forces and mean drift wave forces transfer
Several loading conditions should be considered during the floatover operation because the barge may experience environmental loads from different directions and it will also have different drafts during the mating phase. A typical setting of waves could be as below.

- Wave period: from 3s~30s with 0.5s step
- Wave direction: 0deg~180deg with 30deg step

Since Wadam will automatically detect the mean water level and divide the panel elements crossing it, only one panel FEM model is needed for different loading conditions (e.g. draft).

RAOs (Response Amplitude Operation) may be plotted by Postresp like following examples.

### 3.3 Sensitivity study

A sensitivity study may be conducted to find effects from the panel size to the hydrodynamic analysis results. In general, the panel size near the free surface should be fine enough to get the accurate potential forces.
4 FLOATOVER ANALYSIS

4.1 General description

Broadly, the floatover analysis is divided into several stages.

An example of stages during passive floatover could be as below.

1) Standby: The barge with topside is moored in a safe distance from the substructure to start the preparations, such as the vessel’s ballast system, waiting for the installation weather window. For standby stage, operation and survival conditions can be checked.

2) Entry (docking): The barge position is controlled by winching in/out the mooring system to enter the jacket slot. An additional mating mooring system that connects the barge to the jacket is normally used to assist the positioning.

3) Pre- and mating: The environmental loads are balanced by the mooring and mating systems that keep the barge in position.

In pre-mating phase, the barge is ballasted down to match the LMUs with receptors on top of the substructure legs. The remaining tie-downs are then removed. The stabbing cone is just in contact with the docking cone and none of topside weight is transferred yet.

In mating phase of passive floatover operation, the vessel is ballasted rapidly to lower the topside onto the substructure until the entire topside weight is transferred.

4) Undocking and exit: The barge is continuously ballasted to create a gap between the underside of deck and the vessel’s Deck Support Frame (DSF) and then the vessel is withdrawn from the jacket slot.

A continuous time-domain approach, which includes above phases, can be simulated in Sima simultaneously, while industry practice also provides the approach to separately check several key steps for each stage (loading condition). An example is shown below.

<table>
<thead>
<tr>
<th>Steps</th>
<th>Entry</th>
<th>Pre- and mating and load transfer</th>
<th>Undocking and exit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bow past Row4</td>
<td>0%</td>
<td>Mating position</td>
</tr>
<tr>
<td>2</td>
<td>Bow past Row3</td>
<td>10%</td>
<td>Bow past Row1</td>
</tr>
<tr>
<td>3</td>
<td>Bow past Row2</td>
<td>50%</td>
<td>Bow past Row2</td>
</tr>
<tr>
<td>4</td>
<td>Bow past Row1</td>
<td>75%</td>
<td>Bow past Row3</td>
</tr>
<tr>
<td>5</td>
<td>Topside centered slot</td>
<td>90%</td>
<td>Bow past Row4</td>
</tr>
<tr>
<td>6</td>
<td>/</td>
<td>100%</td>
<td>/</td>
</tr>
</tbody>
</table>

4.2 Coupled and de-coupled analysis

During the floatover analysis, users can choose either coupled or de-coupled approaches. In general, during coupled analysis, all slender structures (mooring lines) will be simulated as FE (beam or bar), and connected to the vessel with master-slave supernodes, thus the interaction of floater mean position and dynamic responses due to slender structure restoring, damping and inertia forces will be calculated simultaneously. Consequently, the analysis time will increase slightly.
In a de-coupled analysis, the mooring system is calculated by traditional catenary formula with quasi-static derivation. In addition, the solving time will be faster.

Sima provides both alternatives, making the analysis very flexible and allowing the user to compare the results from different methods.

In most cases of floatover, de-coupled analysis may be sufficient, since the water depths are relatively shallow and the dynamics from the mooring system are insignificant. However, if the mooring system becomes complex, e.g. moorings with several buoys, the catenary method may not be able to find a proper single solution with quasi-static derivation, and an advanced FEM should be used. In addition, if some extra check needs to be done for the mooring, such as clearance check between moorings and on-bottom pipes, FEM is recommended to get more accurate displacements of each node on the mooring lines in each time step.

4.3 Environments

The environment settings in Sima are straightforward. Wind, waves, current and swell can be input directly from the GUI. Different types of waves and wind can be selected. And the spectrum or profile plot will be automatically generated by Sima and can be used to check the parameters or in the report, as shown below.

4.4 Bodies

Six or three DOF (Degrees of Freedom) or fixed bodies can be defined in Sima. For example, in floatover analysis, the barge and topside can be defined as large 6-DOF bodies with the jacket defined as fixed bodies.

4.4.1 Geometry

Geometries of the bodies can be defined with different methods. In the initial design phase, or for simplicity, users can choose to use several basic types of geometries, such as box, sphere, or cylinders. In addition, external geometry file can be read in for the purpose of visualization. Sima supports different file formats and for Sesam users, we recommend to use *.obj files. See 3.1 as well.

Though the geometry of bodies will not be used in the calculation, they are still very useful for the checking of models, relative positions, and components settings during the analysis.
4.4.2 Interface with hydrodynamic modules

For floating structures, Sima provides the interface with hydrodynamic results files from HydroD. The retardation function will be calculated simultaneously from added mass and damping coefficients, which will be used later during the integration in time domain calculation.

By importing the interface files, the hydrodynamic coefficients could be presented directly from Sima GUI. This very useful function allows users to directly check those data before wasting too much time setting the floatover model if there is an error in the hydrodynamics.

4.4.3 Wind and current forces coefficients

Wind and current coefficients can be manually defined in Sima, as well as damping. Those data can be either calculated by empirical formula or CFD method, or obtained from model test.
4.4.4 Mooring

If quasi-static method is chosen to simulate the moorings, mooring lines will be defined under the Body settings in Sima. Users just need to define the segments along each line first as below.

For line definition, there are three methods.

- Anchor position specified by horizontal distance and direction
- Anchor position specified by global x,y
- Anchor position specified by line pretension

In addition, Sima has a powerful function to switch among different methods, which means users can define the line in one of the three methods and convert the data into the other two methods.

If coupled analysis and FEM is preferred, the line definition is independent to Body settings. Supernodes, which represent fairlead and anchors, need to be specified first and users need to define detail properties of each cross section.

Buoy definition is available in both methods. Position-dependent buoyance is possible to consider as well. In many engineering practices, buoys on the mooring are simulated as vertical forces. If those practices are followed, special check is needed to make sure the vertical forces do not pull the mooring lines out of the water.

4.4.5 Dynamic Positioning (DP) control

As an alternative to use mooring, the DP system may be used to control the positions of the barge in a horizontal plane. Sima provides thruster definition and DP control system definition. More details will be explained in a separate white paper.

4.4.6 Mating line

A mating mooring system is normally used to connect the barge with the jacket legs during entry to ensure the engagement of LMUs.

In Sima, the mating lines could be simulated as spring elements with specified length-force relation connected to a Body, while the relation (stiffness) can be either linear or non-linear, and length-damping relation could be defined at the same time.
4.5 Coupling components

Sima provides various objects to simulate the components needed in different kinds of marine operations, such as docking cone, fender, bumper and lifting lines, etc.

4.5.1 Deck Supporting Unit (DSU) and Leg Mating Unit (LMU)

DSU and LMU are critical components during the floatover analysis and must be simulated carefully.

The DSU normally consists of linear compression-only stiffness in the vertical direction and the linear springs in the horizontal direction. Structural stiffness between the topside and barge should be considered by modifying the stiffness. For the vertical stiffness, fenders with nonlinear stiffness could be used. For the horizontal stiffness, either docking cones or frictions and shear stiffness could be used. Another option is to use x- and y-direction springs. However, since the topside may move in an arbitrary direction, special consideration needs to be made to set up the springs. An illustration is shown below[3].

The LMUs also consist of vertical and horizontal elastomer units, which absorb energy and impact during the mating operation. The horizontal stiffness is from both the jacket, deck structure and the elastomer ring of the LMU, while in the vertical direction, it is a combined stiffness of the elastomer units, the jacket and deck structures. In Sima, a docking cone is used to simulate the stiffness in horizontal direction and a point fender for the vertical direction. Compared to using horizontal x- and y-springs, this method is closer to the engineering concept since contact point between the docking pin and docking plane is unpredictable.
4.5.2 Fenders

The fenders are installed along each side of the barge to limit the surge and sway motion of the barge, and to reduce the impact loads on the jacket legs.

Considering motions of the barge, the contacting positions normally vary in each time step, thus line Bumper component (bumper line) is normally used to simulate those fenders, as shown.

4.6 Result evaluation

There are several ways to check the results in different levels. After every analysis, users can effectively check the static and dynamic analysis results by browsing the folders in the navigator.

For static results, an overview can be shown by double clicking on the prs.lis file. This is a good way to check the equilibrium position after static analysis and see if there is an obvious error, e.g. if the vessel has a large vertical displacement change. Normally that means the balance needs to be rechecked.

By double clicking on the results.tda in Dynamic folder, different time series of variables can be shown.
To run detailed post-processing, separate post-processing tasks could be created with different specifications. There are many useful functions in the post-processor, including arithmetic, statistics, filtering, spectral analysis and fatigue, etc. Below shows a simple example in which the fender forces were extracted from all the signals and plotted. Max value of the same signal was then plotted as well.

More advanced post-processing can be specified as in the below example, in which you can get both plot of time series with specified signals and the statistics.
Furthermore, if we want to check the distribution and estimate the extreme values of the line tensions, we can create Distribution processor under Statistics and use Rayleigh distribution. We may get estimated extremes of each line with probability of non-exceedance as below.

4.7 Clearance check

In many floatover operations, to avoid clash between the mooring lines and on-bottom pipelines, buoys need to be added on the mooring lines and a minimum clearance check is necessary. In some projects, due to the limitation of other software used, engineers had to manually calculate a catenary shape when the moorings lines had minimum tension, and check the distance of lowest point(s) on the mooring lines. This approach does not necessarily provide conservative results, thus makes the operation more unpredictable.
Sima provides a more accurate solution to check the clearance. To use this function, the mooring system was simulated as FE beams. As a result of time-domain coupled analysis, the displacements of all nodes along the mooring were reported. In the post-processing, the user can specify to check the distance either between one movable line and a fixed line, or two movable lines. In this case, we assume the on-bottom pipelines are fixed. In the following workflow specification, clearance of mooring line on the port side (FP) and three on-bottom pipelines, and mooring line on the starboard side (FS) and one pipeline are checked. The results were combined and the minimum value of all clearances was plotted.
4.8 Report

Sima has a report generator that can be used to generate various types of reports using data from both Sima and external resources. One can combine for instance text, formulas (written in LaTeX) with plots and statistics from the post-processor; then generate the report and get the result as a file in Office Open XML format (OOXML), editable in Microsoft Word and other applications.

Formulas expressed in LaTeX are automatically converted to OOXML and can be edited using the word processor tools. The same goes for tables and charts.

5 USE OF VARIABLES

In Sima, most of the parameters can be defined as variables. Different values can be given to the variables defined, and depending on the types of analysis specified, Sima has the capability to run either one or several analyses with different combinations of variable values. Parallel execution is also possible, which may save a tremendous amount of analysis time.

This function can be very useful, for example when our users want to conduct a parameteric design or analyse the same system under different environment conditions. Then the results can be plotted in the same figure to compare.
6 REFERENCES


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