WaveLand JIP:

Wave Impact on FPSO’s and Floating Platforms

Reliable methods and robust tools for design and verification of floating production units against wave impact.

Phase II: Run-up and extreme waves on floating platforms and large-volume structures; semis, TLPs, SPARs and gravity based structures.

Critical situations caused by wave impact in platform decks are receiving growing attention. Such situations may be caused by extreme wave situations or by local diffraction and run-up around platform columns. Subsidence of gravity-based structures require renewed attention to air-gap, run-up and water impact loads. And increased loading or tie-in of new satellites prompts similar considerations for floating platforms. There is a continuous development of advanced methods on different parts of the problem, e.g. nonlinear and random waves, complex vessel motions, wave diffraction etc. To date, however, a consistent design tool combining the complete chain of events in an engineering format does not seem to be available.

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Run-up tests with 4 columns with 45 degrees wave heading; waves propagating from left to right.
Wave Impact on FPSO’s and Floating Platforms

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To address these needs, MARINTEK has launched a JIP project to develop reliable methods and practical design tools for engineering use. The first phase of the project focused on bow slam and water-on-deck loading on ships and FPSOs. This phase is now completed. Phase II of the project will focus on run-up and wave impact on floating platforms and large-volume structures, i.e. semis, TLPs, SPARs and gravity-based structures.

A semi-empirical approach is taken, in which analytical formulations are calibrated against model test data. The objective of the development is to establish reliable tools for the prediction of:
- probability of run-up and wave impact on floating platforms
- design loads for water impact loads
- structural integrity
- effect on global motions of the platform

Sponsorship
Phase I of the project was sponsored by Norsk Hydro, Statoil, Petroleum Geo-Services (PGS), Advanced Production & Loading (APL), NAVION, Rolls Royce Marine and the Norwegian Petroleum Directorate (NPD). Phase II was launched this winter, and was very well received by the offshore industry. Initial work will start late 2002, with the main thrust starting early 2003.

Water kinematics and relative motions
Incoming waves are simulated by a second-order random wave model, which describes wave elevation as well as kinematics. Vessel motions are calculated with slow-drift motions taken into account. Second-order diffraction is used to determine the diffracted wave field.

Relative motions are estimated by combining the second-order vessel motions, second-order incoming waves and second-order diffraction. The relative motions are used to assess the probability of run-up or water impact. Initial conditions for the water flow up platform columns are estimated from the relative wave kinematics; inflow conditions are calculated at selected points as continuous time series of $h_i(t)$ and $v_i(t)$. Systematic model test observations are used to check and calibrate the models. Empirical corrections can be applied to the calculated in-flow conditions.

Water propagation and local loads
The highly non-linear vertical water flow up the columns are simulated by a shallow water approach, extended from the one implemented for Green Sea flow in Phase I of the project. The formulation is reformulated in polar coordinates on the vertical surface of the columns. The effect of gravity is included.

Time-varying boundary conditions for the local water flow are estimated from the relative wave kinematics described above, given in terms of time-variable vertical fluid velocity and time-variable flow thickness at the boundary.

Water impact loads are calculated with a similarity solution whereby the impacting water is described as a wedge with an angle $\alpha$ that travels with velocity $v$ just before the impact. The two parameters $\alpha$ and $v$ are predicted by the shallow-water formulation. The pressure distribution as a function of time and space is then calculated as input to the structural integrity assessment.

Loads on secondary structures in the path of the water flow are calculated using Morison’s equation with the calculated water particle velocities.

Structural integrity assessment
Calculated impact loads are mapped onto existing FE models (NISA, SESAM, ASAS) for simulation of the structural response for each specific impact scenario. A special module based on Biggs’ and Baker’s methods is implemented for screening of admissible water impact scenarios.

MARINTEK contact: Oyvind.Hellan@marintek.sintef.no

The CARISIMA JIP

CAtenary RIser/Soil Interaction Model for global riser Analysis

Steel or titanium catenary type risers are suggested as cost effective alternatives to flexible risers even for medium water depth, but particularly for deeper water (>300 meters). Risers with simple tubular cross-sections offer several advantages over flexible risers built up from numerous layers of different materials.

Existing analysis tools for riser response have proven reliable for most types of risers. However, in the area where catenary risers are resting on the seafloor (refer Figure 1), existing models for riser/soil contact are too simplified to capture the complexity of the interaction. Some of the key findings of earlier work are that the fatigue life predictions at the touch down area (TDA) are sensitive to the FEM modeling, fatigue accumulation procedures and, in particular, the soil model.

Hence, an important step forward in improving riser analysis tools is to improve the riser/soil interaction model. This issue has been the key objective of the CARISIMA project.

Organization
The CARISIMA work has been organized as a Joint Industry Project (JIP) with MARINTEK and Statoil as executive partners, and with The Norwegian Geo-
The CARISIMA JIP
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technical Institute (NGI) as sub-contractor for execution of the laboratory tests. The project was kicked off during autumn 1999, and will be terminated within spring 2002. The overall budget is 5.0 MNOK in external funding, plus 1.5 MNOK as in-kind contribution. The work has been sponsored by BP, Conoco, Statoil, Norsk Hydro, ExxonMobil, Agip, Texaco, Petrobras and Halliburton.

Laboratory tests
The CARISIMA model development has been based on small-scale laboratory tests performed by NGI. The tests were performed in two phases, phase 1 (14 vertical and 17 horizontal tests) was completed during spring 2000, and phase 2 (10 vertical and 6 irregular tests) was completed during spring 2001.

The clay was taken from a NGI reference site at Onsøy, in the south-east part of Norway. A cement truck was used to transport the clay from Onsøy to Oslo. At NGI the clay was filled into 4 steel bins, and left to consolidate under dead weight for six weeks or more.

Originally, the NGI test rig was designed to be configurable depending on what type of tests to perform, ie, either vertical tests (suction) or horizontal tests (pullout). However, when designing the test series for phase 2, it was decided to modify the rig to allow for simultaneous motion of the pipe sample both vertically and horizontally. Hence, an additional actuator was installed, and the test rig ended up as illustrated in Figure 2.

The vertical and horizontal loads (or displacements) was applied to the model by one horizontal and one vertical actuator. Both actuators were equipped with low friction seals. The actuator system is servo-hydraulic (servo valves on actuators controlling oil flow from constant speed and pressure pump) and closed-loop (operation based on measured performance feedback). As the actuators move, the pipe sample will also move. Stroke range for the horizontal actuator is ±500 mm, for the vertical actuator ±80 mm. Controlling the actuators is done through a computer-based operating system, consisting of a control unit and a PC program.

The main parameters logged during execution of the tests (both vertically and horizontally) were load, displacement and acceleration.

Model development
The raw test data as acquired during the tests went through massive post-processing procedures before generally ending up as dimensionless functions of typically force and displacement (penetration), as illustrated in Figure 3, where all results from the vertical tests in phase 1 are shown.

For the vertical tests, one of the important observations made was that the mobilised soil resistance was very dependent of the lift-off velocity, as illustrated in Figure 4. Hence, this effect has been incorporated into the numerical model.

Verification and validation
The developed numerical model has been verified by back-calculation of the small-scale laboratory tests at NGI. Furthermore, as part of an information/data exchange agreement between CARISIMA and the STRIDE JIP (www.stridejip.co.uk), the CARISIMA project gained access to all results from the full-scale Watchet Harbour riser/soil interaction tests. The tests were carried out in spring 2000 in a tidal harbour in West England using a 110 m pipe of 16.83 cm diameter. An actuator was used to introduce vertical or horizontal motions similar to those experienced by a Gulf of Mexico catenary riser (the test site setup is illustrated in Figure 5).

The CARISIMA riser/soil interaction model, as implemented in MARINTEK’s RIFLEX software, was validated by back-calculation of a selection of the test series performed at Watchet Harbour.

Deliveries
The main result from the CARISIMA JIP is a mathematical model for riser/soil interaction in clay. The model has been designed for implementation into existing computer codes for global riser analysis and is able to predict both vertical (suction) and horizontal soil resistance. It has sufficient accuracy to give reliable predictions of fatigue life and extreme stresses in the touch down area.

Furthermore, due to the inherent complexity of the model, another important delivery from the project is a guideline to support the designer in applying the model when performing riser analyses.

MARINTEK contact:
Egil.Giertsen@marintek.sintef.no

Figure 1.
Riser/soil interaction for catenary risers.

Figure 2. The NGI test rig.

Figure 3.
Results from the vertical tests.

Figure 4.
Effect of lift-off velocity on suction.

Figure 5. The test rig setup at Watchet Harbour.
Logistic challenges

In multi-modal transport, a variety of documents and information needs to be exchanged between shippers, transport companies and consignees as well as authorities, insurance companies, etc. The need for communication and amount of information naturally increases with the number of partners involved in the transport chain. The TCMS (Transport Chain Management System) system was developed to make this easier. To ensure flexibility it has been designed with a modular philosophy such that components and information can be reused across the different sectors.

Process and workflow modelling

To be able to capture a new transport market and to serve your customers in a best possible way, you first need to know your own core business, second you need to know your role in given markets and transport chains. Process modelling may serve as a tool to establish this knowledge internally as well as to communicate it externally to customers and other actors in the marketplace. Other areas where process modelling has proved to be valuable is as basis for all kinds of business improvement initiatives ranging from pure process improvement via benchmarking and ICT development to logistics flow analysis and improvement.

There are several approaches to process modelling, how it is done and documented. Normally an overall model of your core processes and products will serve as a starting point. An alternative is to go more into details on stakeholders and internal and external relations. In logistics studies, more focus is put on the cargo flow and the overall model will reflect main transport legs, terminals and co-ordination of the flow. In all cases there will be a need to document more process details in way of workflow descriptions. A workflow depicts roles, activities and information systems and how they relate, i.e. activity sequence and information flow between activities and systems.

Architecture

A multi-modal system architecture for freight transport has been developed and refined during several projects funded by the European Commission and by the Norwegian Research Council. The system architecture is a harmonisation of requirements from a large number of European transport actors, and is composed of sub-models covering functions, information and communication aspects.

The system architecture consists of the following parts:

- Functional Architecture, which describes the business processes in the multi-modal transport chain. The business processes cover the main phases in the transport chain (pre-, during-, post-transport): Order goods, prepare transport chain, prepare transport, perform transport and monitor transport. The business processes have been grouped into a component model, which contains the building blocks (components) of multi-modal systems.

- Information Architecture, which is presented as TRIM (Transport Reference Information Model). TRIM defines the data needed by the information systems along the transport chain, and describes how the data are structured. TRIM is structured in 18 submodels, and each submodel contains detailed definitions of entity classes, relationships and attributes. TRIM can be implemented as a database for each actor or as a shared database for multiple actors.

TRIM interfaces.

TCMS is a conceptual information model, and has as such two important features:

1. The model is independent of technological platforms; operating systems, data base management systems and communication systems.
2. The model is independent of organisational structures, because of the modelling technique applied.

These two properties imply that TRIM is very stable, and will not change because of new technology or changes in the organisational structures. TRIM can be downloaded from the following site: 
http://www.informatics.sintef.no/trim/

- Physical Architecture describes the grouping of components into information systems. Each actor will have the possibility to assemble components to an information system, based on his needs.

TCMS

TCMS (Transport Chain Management System) is a fully Web-based system to be used to control a door-to-door transport where several transport modes are involved. The TCMS system architecture defines a common framework for how to integrate information systems in a multi-modal transport chain. The system will provide and help to convert the information an actor in a chain requires. TCMS automates the exchange of information and documents needed for the organisation of multi-modal transport in such a way that the user has no additional effort compared to uni-modal transport. Communication interfaces and message formats can be chosen individually for each participant. TCMS delivers its service independently of the internal organisation of the participating enterprises, and does not require specific software at the participants’ site.

MARINTEK contact:
Kay.Fjortoft@marintek.sintef.no