SINTEF

Invitation to a Joint Industry Project on DROPS — *Dynamic Response of Offshore Pipelines on the Seabed*

Subsea pipelines are designed to transport high temperature and often hot toxic hydrocarbons, while interacting with the seafloor and environmental actions. Precise and reliable modelling of this interaction is of key importance in order to obtain a robust yet cost effective design. The overall objective of the DROPS JIP is thus to improve how we predict and implement pipe-soil interaction and pipe-external wave and current actions in design. This shall be performed by establishing an improved set of numerical models through research and shall involve:

- Hydrodynamic load models taking due account of recent developments in the field, including waves, current and local seabed topography, also applicable in shallow water
- A new generation of numerical models for pipe-soil interaction

Better prediction of pipe-soil interaction is important for obtaining better confidence in how the pipeline interacts with the seabed during operation and installation. A more reliable hydrodynamic model is especially advantageous for shallow water and opens up for less conservative designs whilst still conforming with the defined limit states.

The developed models will be implemented and made available to the industry through the tailor-made pipeline analysis software SIMLA. This will provide a full featured engineering tool for assessment of the on-bottom stability considering 3D seabed topography with improved pipe-soil interaction models and optimized hydrodynamic load prediction methods for offshore pipelines, umbilicals and cables.

BACKGROUND AND OBJECTIVE

Hydrodynamic loads and interaction with soil are important elements for determining the response of a pipeline resting on the seabed. The soil resistance determines whether the pipeline systems ability to anchor axial forces, how the pipeline develops global buckles, and whether the system is vulnerable to environmental and third party loads. The environmental loads in combination with soil resistance, in turn, play a role in determining the lateral stability of the pipeline.

Identifying and preventing lateral instability as a failure mode is typically important for shallow seas or near coastal areas / landfalls. Analysis of such behaviour may either be performed by CFD or by simpler and more efficient solvers such as the SINTEF Ocean developed time-domain based FE software PONDUS. The software solves the response of the pipe for a straight pipeline in 2D on the horizontal plane using small deflection theory.

The PONDUS software bases itself on linear wave theory and an advanced soil formulation; all documented through journals since the mid 80s. The value of having a fast and reliable numerical tool for performing on-bottom stability analyses is imperative. However, there is potential for improving the system yet more. The objective is therefore to export the qualities of PONDUS to the overall capability of SIMLA such that the stability response can take advantage of uneven terrain and free spanning, as well as being performed on one single platform.

As part of developing the on-bottom stability performance for SIMLA, we see potential for improving models for predicting the pipe-soil interaction. This is not only important for lateral stability when subjected to sea loads. It applies to all aspects of pipeline response engineering. For instance, soil resistance takes part in determining when pipelines buckle, the curvature of the buckle, the axial feed in, and how the pipeline resists third party actions, e.g. from trawling. Often the soil resistance is given in terms of

1) Through an internal merger in the SINTEF Group, MARINTEK is now part of the new unit SINTEF Ocean. This is a merger of MARINTEK, SINTEF Fisheries and Aquaculture and the department for Environmental Technology at SINTEF Materials and Chemistry.

multilinear resistance-displacement curves that are uncoupled in the principal directions. The resistance curves are often bound with a large variability between lower and upper bound that shall cover the uncertainties regarding the present modelling scheme. The variability between upper and lower bound is often significant and leaves room for improvement. A consequence of such improvement can be better prediction of buckle locations, shorter curve radius during installation and more accurate on-bottom stability response. This may in turn have an effect on installation costs and increases the confidence for predicted response during planning.

Motivated by a more precise and robust prediction on on-bottom response , SINTEF Ocean, plans to improve soil methods for how soil can be in SIMLA. As part of this, SINTEF Ocean also plans to qualify Coupled Eulerian-Lagrangian (CEL) methods to provide methods for modelling more advanced geotechnical problems that can may not be sufficiently solved using the spring formulation in SIMLA. This includes problems involving severe soil deformations, such as ice-scour in arctic applications, riser TDZ, flowline lateral buckling and on-bottom stability, and other geotechnical applications. The CEL / ALE applications will not be implemented into SIMLA but will be qualified through other general purpose FE software such as ABAQUS or LS-DYNA.

WORK DESCRIPTION

In 2001 SINTEF Ocean started the development of SIMLA — a special purpose computer tool for engineering analysis of offshore pipelines during design, installation and operation. The initial objective of the SIMLA development was to simulate the structural response of a pipeline during laying, and to inspect the result of such analysis by 3D graphical visualization of the laid pipe on the 3D seabed, including pipe details with analysis results.

A full featured engineering tool for prediction of the on-bottom stability considering 3D seabed topography can be built upon the framework of SIMLA by integrating the following functionalities:

- The soil-pipe interaction in three directions is already modelled by three uncoupled spring elements in the current version of SIMLA. This approach has been proved very efficient and robust in analysis of the global pipeline response. This approach can be extended to a more generalized 3D pipe-soil interaction model taking into account the coupling effect and the formation of berms could be implemented in SIMLA to improve the capability and reliability of the pipeline response analysis.
- A proper hydrodynamic load model for prediction of the hydrodynamic loads acted on the pipelines and cables. The basic model will be an enhanced PONDUS model due to its maturity and robustness compared to other recent developed models by considering benefits from DNV GL's "unified approach" which will be the outcome of the ongoing pipeline stability JIP PILS.

VALUES AND BENEFITS

- Full 3D nonlinear time domain on-bottom stability analysis
- More accurate estimation of pipe/seabed penetration during installation
- More accurate estimation of pipe/soil interaction effects, including self-burying and break-out resistance, in upheaval buckling and snaking analysis
- More accurate estimation of pipeline walking related to operation start-up and shutdown

WORK PACKAGES

WP1: Pipe-soil interaction models

- Review of existing models and available test data
- Identify gaps
- Qualify CEL methods
- Development and implementation of new global models for pipe-soil interaction
- Verification

WP2: Hydrodynamic load models

- Review of existing models and available test data
- State-of-the-art literature review; Identify gaps
- Development and implementation of new hydrodynamic load models
- Verification against previous and literature results

DELIVERABLES

The main deliverable will be a new SIMLA version with full capability of on-bottom stability analysis, together with technical reports and case studies.

One free SIMLA server license will be offered to all sponsors during the project (training and support to be paid separately). All sponsors not having SIMLA at project kick-off will be offered licenses to further use of SIMLA after the project period by only paying the maintenance fee for the requested licenses.

SCHEDULE AND PARTICIPATION FEE

Duration:	Q3/2017 - Q3/2019 (2 years)
Participants:	Energy companies, Contractors, Suppliers and Engineering companies
Sponsor fees:	1 000 kNOK per participant for Energy companies, 500 kNOK for Contractors/Suppliers and 300 kNOK for Engineering companies

SINTEF

CONTACT US FOR MORE INFORMATION:

Janne K. Ø. Gjøsteen
Research Manager
Phone: +47 406 41 450
Janne.Gjosteen@sintef.no

Naiquan Ye
Senior Research Scientist
Phone: +47 470 78 619
Naiquan.Ye@sintef.no