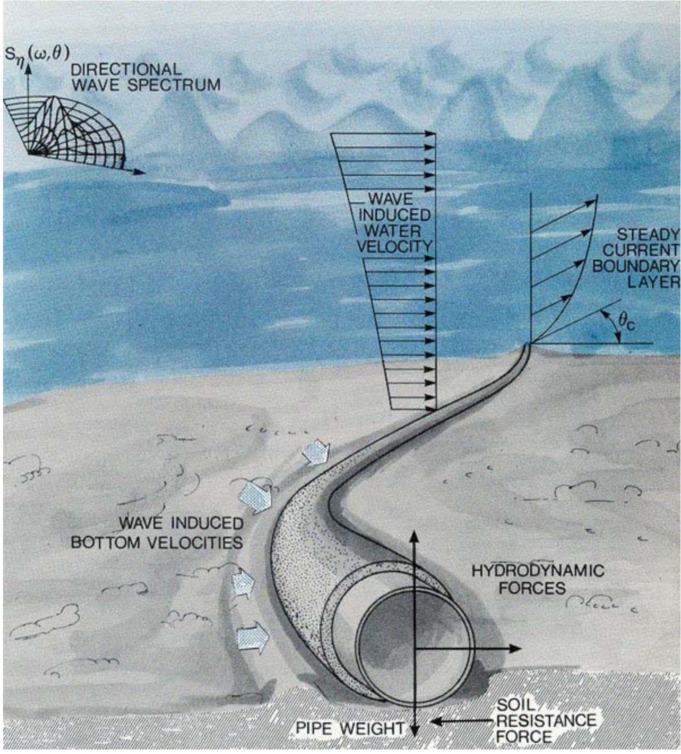
DROPS JIP Phase I

Q3/2017—Q1/2021



Through the DROPS JIP Phase I, SIMLA has become a full-featured engineering tool for dynamic on-bottom stability analysis of subsea pipes considering real 3D seabed topography.

The development was focused on the implementation of the state-of-the-art hydrodynamic load model (Sotberg et al. 1994) and the most robust and reliable pipe-soil interaction models for both sand (Verley and Sotberg 1992) and clay (Verley and Lund 1995). SINTEF Ocean's special pipe-laying software program SIMLA was chosen as the numerical framework for the implementation because of its inherent 3D features for modelling of pipes on uneven seabed terrain under complex environmental loading. Several weak points in PONDUS software were identified and replaced by robust algorithms from the framework of computational plasticity.

The following features have been implemented in the SIMLA software program for the assessment of the on-bottom stability of pipes :

- An improved version of the pipe-soil interaction model for sand developed by Verley and Sotberg;
- An improved version of the pipe-soil interaction model for clay developed by Verley and Lund;
- The PONDUS database hydrodynamic load model has been extended to 3D analysis including presence of gaps between the pipeline and the seabed.
- Time-controlled hyper-elastic springs for seabed contact elements. These springs are intended for use in static analysis to avoid a singular equation system due to lack of pipeline boundary conditions. The springs have been shown to be helpful also in cases where it is difficult to obtain convergence during start-up of static analyses;
- Penetration-dependent hyper-elastic curves for modelling of additional soil resistance in the axial direction. This modelling option has previously only been available for the lateral direction (referred to as "hat"-curve);
- Modelling of initial soil embedment as a function of KP. The initial soil embedment is considered for the soil resistance in the sand and clay models, as well as for the penetration-dependent additional soil resistance in the axial and lateral direction;
- Tables for defining data arrays for gap-dependent hydrodynamic coefficients, initial soil embedment, KP-based trench reduction factor for the DROPS hydrodynamic loading, and soil penetration-dependent load reduction factor for the DROPS hydrodynamic loading. Surface roughness including the marine growth effect
- Regular wave modelling was implemented for the hydrodynamic loading. This wave model is particularly useful for parametric studies and model verification purposes;
- Blocking of time series for wave kinematics and pipe hydrodynamic loads. This feature avoids lack of memory in long-duration analysis for long pipes;
- User controlled de-activation of the pre-generated wave kinematics in the vertical direction. This is useful for saving memory for cases where the whole pipeline rests on the seabed.

Benchmarked by PONDUS

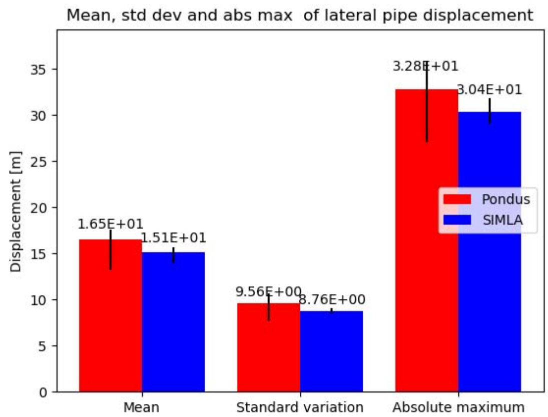
The implemented pipe-soil and hydrodynamic load models were verified against the PONDUS software and excellent agreements were obtained through extensive comparative analysis.

A significant enhancement of the numerical efficiency was achieved. This is especially beneficial for long duration 3D nonlinear time domain analysis. The new formulations give convergence for time step sizes up to 0.05s against 0.01s for sand, 0.001s for clay in PONDUS, and 0.001s in PILSS (DNV 2017) regardless of the soil types.

Case 1: Short model on flat seabed

The base model is a 2 meter long pipe with 0.324 m outer diameter laying on the flat seabed in 30 m water depth. The elements used in both SIMLA and PONDUS are linear with respect to material properties. 7 realizations each with 16385 s are ran for each load case. The results are compared statistically in terms of the mean, standard deviation and maximum of pipe lateral displacement or as time traces of the lateral displacement.

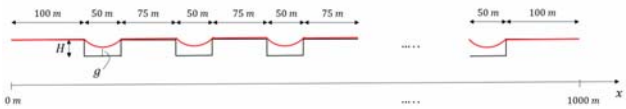
Load Case	Description
LC1	Current velocity of 0.1 m 90°on pipe
LC2	Pierson-Moskowitz spectrum 3.5 m significant wave height
LC3	LC1 + LC2
LC4	Model as LC3. Coulomb friction with varying contact damping
LC5	Model equal to LC4, with varying vertical soil stiffness's
LC6	Equal to LC4 with varying lateral soil stiffness
LC7	Equal to LC6 with 10 % soil contact damping
LC8	Equal to LC7 with varying time steps
LC9	Equal to LC4 with Hs of 2.5 m
LC10	Equal to LC3 but with wave and current angle of 45°
LC11	Equal to LC9 but with wave and current angle of 45°
LC12	Equal to LC10 but with a wave spreading function
LC13	Equal to LC11 but with a wave spreading function
LC14	Equal to LC12 but with Jonswap spectrum
LC15	Equal to LC13 but with Jonswap spectrum
LC16	Current velocity of 1.0 $m s^{-1}$ with varying height above the bottom.
LC17	Environment as in LC4 with varying model length.

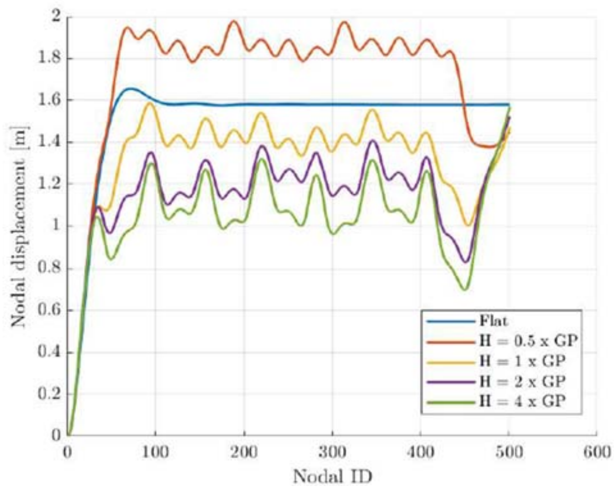


Moreover, the hydrodynamic load model was extended to handle the presence of free spans along the pipeline and to be applicable for 3D analysis. This was done by implementing a Morison load model with gap-dependent lift, drag and inertia coefficients. A linear interpolation scheme was established for weighting the relative contribution from the database hydrodynamic load model and the Morison load model as a function of the seabed-pipeline gap.

Case 2: Long model with free spans

Free spans are placed in the middle of a 1000 m model with an element length of 2 m. Each span has a length of 50 m with an interval of 75 m in between. Span height is varied referring to a specified gap value.





Reductions in hydrodynamic loads are observed due to the presence of the free spans when the height/gap ratio is relatively large. However, The maximum nodal displacement seems to be amplified when the height/gap ratio is approaching zero. Another important finding is that the maximum displacement drops in the free spans while increases at the span shoulders. This indicates a possible transition from the wake force model to the Morison model locally in the free spans.

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