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Reliability-based design of subsea light weight pipeline against lateral stability

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ABSTRACT

The application of non-metallic light weight pipeline (LWP) in subsea oil/gas transmission system is subject to subsea pipeline on-bottom stability problem because of their light weight. Additional weight required for the stabilization of subsea LWP is a critical item to consider when decreasing the cost of the pipeline system. This paper presents an effective approach to determine the additional weight by utilizing a reliability-based assessment of subsea LWP against on-bottom stability. In the approach, a dynamic non-linear finite element model (FEM), including a model of fluids-pipe-soil interaction for the subsea pipeline, is used to study the pipeline displacement response. In-place analysis of a flexible pipe is presented as an example of the authors' methodology. Results show that displacements are largely affected with and without considering the lift force. Additionally, the uncertainties of all parameters used in the model are considered. With 145 cases of FEM calculations being the samples, a response surface model (RSM) is developed to predict the pipeline lateral displacement using the software Design-Expert. Combing with the RSM equation, the Monte Carlo simulation method is employed to estimate the probability of exceeding pipeline stability. To calculate the reliability of LWP for different submerged weights, the method introduces a calibrated factor into the serviceability limit state (SLS) function. The proposed approach can be used to determine the additional weight required for the on-bottom stability of

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subsea pipelines while considering the uncertainties of all relevant parameters.

Nomenclature

LWP	light weight pipeline
FEM	finite element model
RSM	response surface model
LCF	load concentration factor
SLS	serviceability limit state
D	pipeline diameter
W_{sub}	pipeline submerged weight
$\dot{\sigma}$	soil reaction force
$\dot{\varepsilon}$	pipeline displacement
D^{ep}	elastic-plastic matrix
D^{e}	elastic matrix
K	plastic modulus
$S(\omega)$	wave spectrum
ω	wave frequency
ω_p	frequency corresponding to peak period
γ	peak enhance factor
$G(\omega,\theta)$	spreading function
$G_0(s)$	direction distribution
θ	direction angle
θ_j	direction angle component
$\eta(x,y,t)$	surface elevation
x,y,z	pipe node coordinates
$a_{i,j}$	wave amplitude
$\Delta\theta,\Delta\omega$	directional and frequency interval
ω_i	wave frequency component
k_i	wave number corresponding to ω_i
$\phi_{i,j}$	random phase
U_x	horizontal wave velocity
$\dot{U}_x$	wave horizontal acceleration
d	water depth
F_{DD}	drag force
F_I	inertia force
F_L	lift force
C_D,C_M,C_L	drag, inertia and lift coefficients
V_f	near pipe water velocity
V_p	pipe velocity in the horizontal direction
a_f	near pipe water acceleration
a_p	pipe acceleration
Std. Dev	standard deviation
C.V.	coefficient of variation
R-Squared	the coefficient of multiple determinations
PRESS	the prediction error sum of squares