Application of optimisation and an artificial neural network to stabilisation of a load relocated under water

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Abstract

Stabilisation of a load attached to a long rope in offshore conditions is a complex problem. The dynamic model has to take into account not only the motion of a vessel from which the load is lowered, but also large deflections of the rope and the sea environment. The paper presents the dynamic model of a system consisting of a vessel with a winch, a rope with small bending flexibility, and a load. This is a spatial model which uses a modified formulation of the rigid finite element method [1] for discretisation of the rope.

The equations of motion are derived from the Lagrange equations. Using the Lagrange multipliers the equations of motion can be presented in the following form:

$$\mathbf{M}(\mathbf{q})\ddot{\mathbf{q}} + \mathbf{D}(\mathbf{q})\mathbf{R} = \mathbf{F}(t,\mathbf{q},\dot{\mathbf{q}}) \quad - \text{equations of motion} \tag{1}$$

$$\mathbf{D}^T\ddot{\mathbf{q}} = \mathbf{G}(t,\mathbf{q},\dot{\mathbf{q}}) \quad - \text{constraint equations} \tag{2}$$

where: $\mathbf{q}$ is the vector of generalised coordinates,
$\mathbf{M}$ is the mass matrix which includes the added mass,
$\mathbf{R}$ is the vector of reactions at connections between the rigid elements themselves and the vessel,
$\mathbf{D}$ is the coefficient matrix,
$\mathbf{F}$ is the vector of gravity, buoyancy and hydrodynamic resistance forces,
$\mathbf{G}$ is the vector of the right-hand side of the constraint equations in the acceleration form.

The correctness of the model and the computer programme has been checked by comparing the authors' own results with those obtained from the analytical solution for a catenary line and with the results obtained using the finite element method for discretisation of the rope. Good compatibility of the results has been achieved. Due to the high numerical efficiency of the model, it can be applied for a dynamic optimisation problem that involves choosing a rotation angle $\varphi(t)$ of the drum winch which ensures the predefined position, at a given distance δ from the undulating seabed, despite the movement of the vessel (Figure 1).

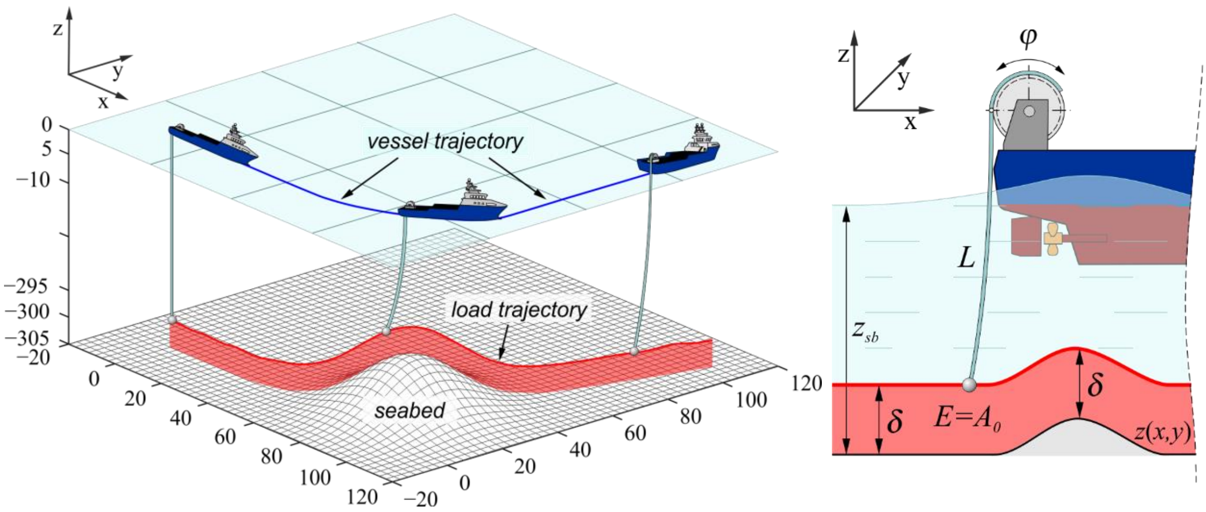

Figure 1 Choice of the rotation angle $\varphi(t)$ of the winch

Function $\varphi(t)$ is approximated by means of the spline functions and the task considered is replaced by the nonlinear optimisation problem. The equations of motion (1) and (2) have to be integrated at each optimisation step.Optimisation calculations have been carried out for different vessel velocities, mass of the load and the height of the waves. This made it possible to design a sigmoidal neural network and approximation of the results of the dynamic analysis. Figure 2 presents simulation results obtained for ANN.

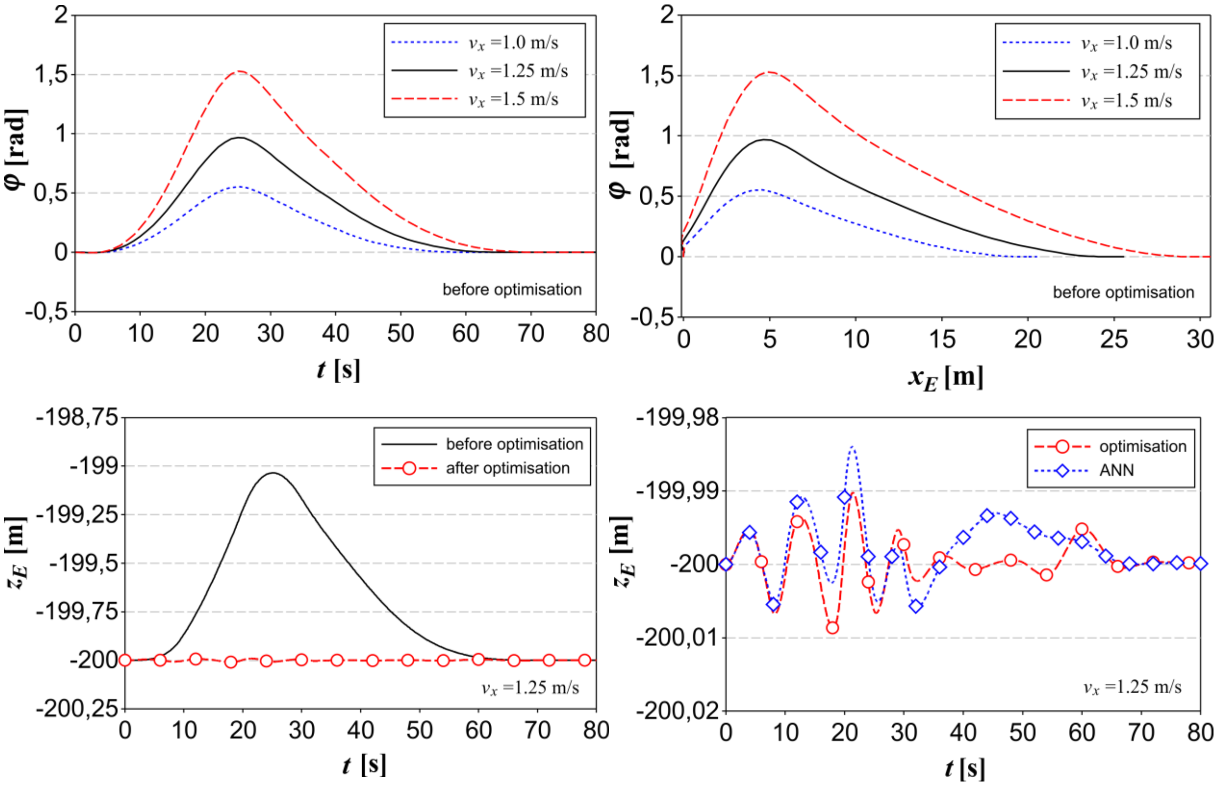

Fig. 2 Stabilisation of the load at the given depth

In the authors' opinion the high numerical efficiency of the model can be used for solving the dynamic positioning of risers by S-lay and J-lay methods.

References

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[2] E. Wittbrodt, M. Szczotka, A. Maczyński, S. Wojciech. Rigid finite element method in analysis of dynamics of offshore structures. Berlin, Springer, 2013.