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TOPOLOGY OPTIMIZATION INCLUDING BUOYANCY INEQUALITY CONSTRAINTS

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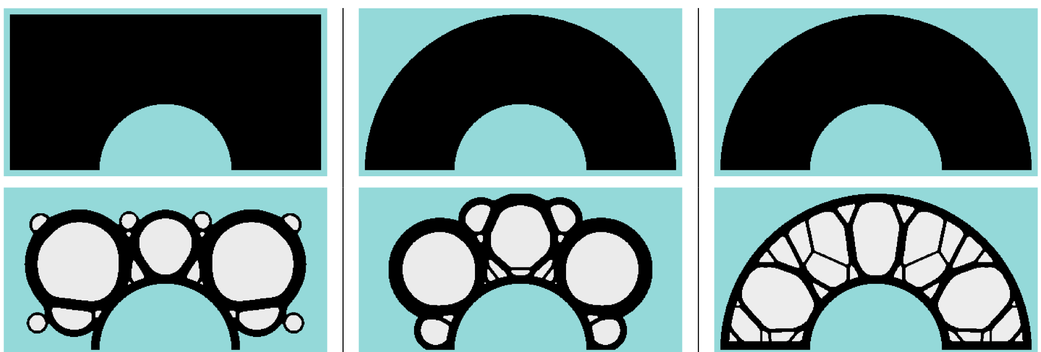
This paper presents a topology optimization method for design of completely submerged buoyancy modules. This type of structures aids to control the formation of lateral buckles along subsea oil pipelines in offshore structural engineering. The proposed optimization method seeks the buoy design that presents higher stiffness and less material attaining a required performance. In order to design subsea polymer buoys, underwater pressure loadings and buoyancy effects must be considered. Pressure loads modeling showed to be a challenging topic for topology optimization [2, 3] and it is still an issue under research [4]. To the best of the authors' knowledge, buoyancy effects were still not considered in topology optimization.

To deal with both pressure loads and buoyancy, a discrete topology optimization method is proposed, the so called Bi-directional Evolutionary Fluid-structural Optimization (BEFSO), which is based on the ESO/BESO methods [5]. This methodology presents some potential advantages in the handling of design-dependent pressure loading problems, in which the discrete nature of the method defines the pressure surfaces explicitly. A hydrostatic fluid is used to simulate the underwater pressure and the polymer buoyancy module is considered linearly elastic. The one-way coupled fluid-structure model is solved with the finite element method. From the initial design domain, inefficient solid elements are iteratively removed until a certain prescribed volume fraction. Buoyancy requirements are introduced as an inequality constraint in the optimization problem. The result buoyancy force is equivalent to the weight of the fluid displaced by the submerged structure. Thus, in order to guarantee some desired buoyancy effects, the entire structural volume (including interior voids) must be as big as possible. The final goal of the optimization problem is then to design a structure stiffest as possible for the underwater pressure load case and also with high buoyancy effects (high displaced fluid volume).

The studied case consists in a buckle migration buoyancy module for subsea oil pipelines. Results showed to be promising. Stiffer buoyant structures could be designed attaining a minimum required buoyancy limit. Figure 1 presents primary results concerning stiffness maximization of a buoyant structure. The term C indicates the compliance and B the entire structural volume, both concerning the final topologies. Examples (a) and (b) from Fig. 1 demonstrate the results of the method moving the fluid-structure interfaces and keeping the entire structural volume upper a certain prescribed limit. Example (c) is a comparison case where the fluid-structure interfaces are kept fixed.



(a)	(b)	(c)
$C = 4.3030 \cdot 10^{-4}$ Nm	$C = 3.7635 \cdot 10^{-4}$ Nm	$C = 5.7643 \cdot 10^{-4}$ Nm
$B = 0.1661$ m^2	$B = 0.1575$ m^2	$B = 0.1856$ m^2

Figure 1: Subsea buoy modules design with topology optimization: (a) initial full design domain (top) and final topology (bottom); (b) initial semicircle solution (top) and final topology (bottom); (c) initial semicircle solution (top) and final topology with fixed fluid-structural interfaces (bottom).

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