TOPOLOGY OPTIMIZATION OF OFFSHORE PLATFORM STRUCTURE PANEL AND EXPERIMENTAL VALIDATION

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1. Introduction

Generally, the design of offshore platform structures is strictly guided by recognized codes and standards (RCS). The series of procedure on offshore structure design is called rule scantling. These regulations and guidelines are mostly empirical and are based on some old-fashioned but reliable safety factor approaches such as working stress design (WSD) or allowable stress design (ASD). Although these codes and standards provide a firm layout of offshore structure, it often result in over conservative design which causes millions of dollars of extra construction cost. In this research, to enhance the structural performance and to suggest a new novel design of offshore structures, we performed a topology optimization [1] based on solid isotropic material with penalization method (SIMP) on a designing process of an offshore platform structure panel. A volume constraint is applied in the optimization problem to utilize same material compared to the rule scantling offshore platform panel design. Since Bendsøe and Kikuchi [2] introduced concept of topology optimization based on the homogenization method, topology optimization has been widely utilized to obtain an optimal structural connectivity to satisfy the required performances. However, optimal design obtained as a result of topology optimization have limitations to apply directly to the design of offshore structures. Inherently, since it relies on the mesh of analysis method, optimal design from topology optimization has a non-smooth stair-wise boundary which is unable to manufacture and lacks usability. To overcome the difficulties we adopted the morphology concept to convert the optimal design into CAD (Computer Aided Design) data and utilized spline fitting based on NURBS (Non-Uniform Rational B-Spline) to enhance the manufacturability and applicability on the design of offshore structure. Later, the smoothed optimal design is manufacture by metal 3-D printing and experimentally validated by comparing the structural performance with the rule scantling based design under compression test with universal testing machine (UTM).

2. Topology optimization of offshore platform structure panel

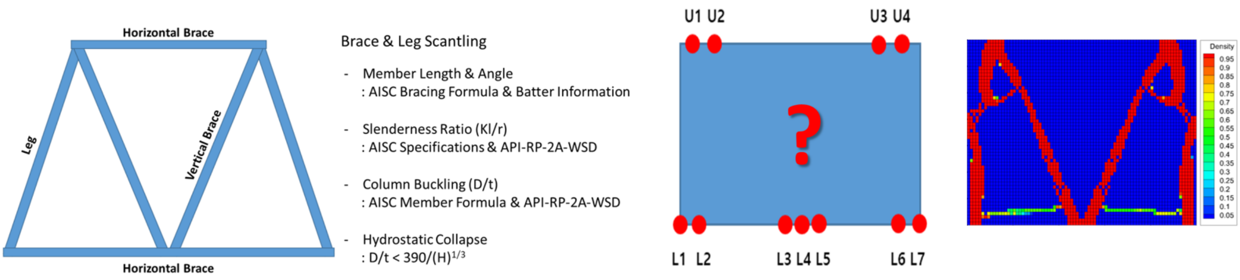
To find optimal layout of offshore platform panel which maximize the structural stiffness, topology optimization is performed to minimize the structural compliance with a volume constraint to use same material as the rule scantling based design, Figure 1 (a). Design domain is considered with the corresponding displacement boundary condition of the rule scantling design as Figure 1 (b) and the optimal layout obtained from the topology optimization is shown in Figure 1 (c).

(1) $$\text{minimize } C = \sum_{i=1}^{NE} f_i u_i \,.$$

(2) $$\text{subject to } \sum_{i=1}^{NE} \rho_i V_i \le V_0 \,.$$

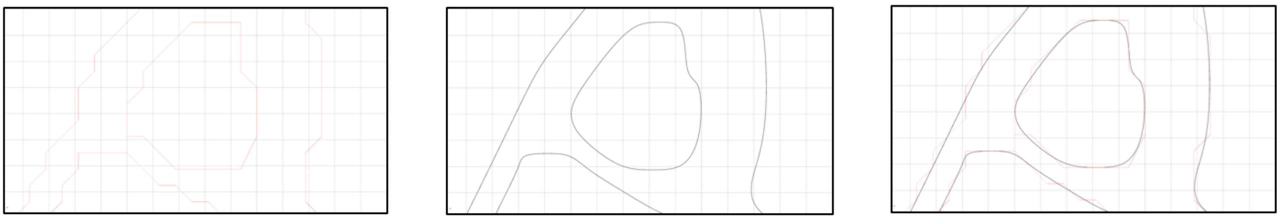
3. Smoothing the boundary of optimal design with morphology and spline fitting

To alleviate the stair-wise boundary of topology optimization, we applied morphology concept and spline fitting. First, morphology concept with dilatation method is utilized to topology optimization result to convert it into CAD data. Later, spline fitting with NURBS is employed to fit two geometric points located on the middle of the boundary of CAD converted optimal design while satisfying the volume constraint stated in the optimization problem (Figure 2).



(a) Rule scantling of offshore jacket structure panel (b) Design domain (c) Optimal design

Figure 1: Offshore platform structure panel and topology optimization

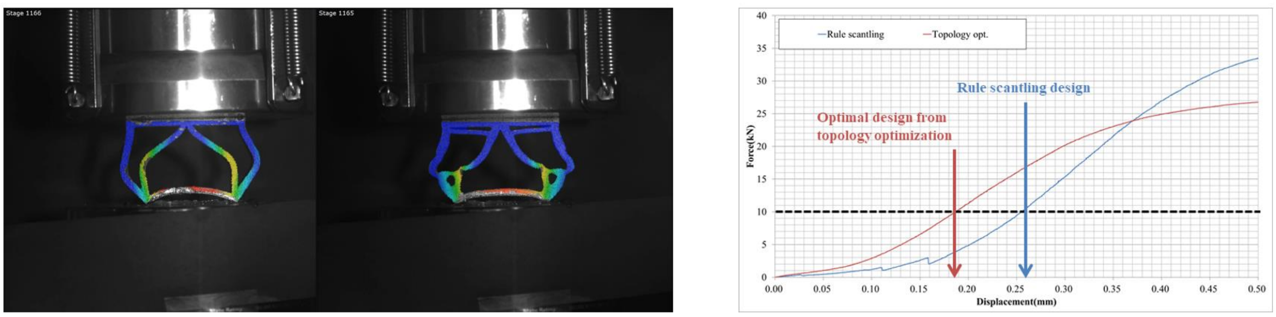


(a) Initial geometry from topology optimization (b) Geometry from spline fitting (c) Overlay of initial geometry and spline fitting

Figure 2: Boundary smoothing procedure by spline fitting

4. Experimental validation

Obtained optimal design of offshore platform structure panel with smoothed boundary is experimentally validated utilizing UTM under compression load by comparing the structural performance with the rule scantling design. As shown in Figure 3 (b), the proposed optimal offshore platform structure panel design has less deformation under same compressive load compared to the original design. The structural performance has been enhanced about 28% from the initial rule scantling design in the elastic region.



(a) Compression test with UTM (b) Displacement comparison under compression

Figure 3: Experimental validation of proposed optimal design of offshore platform structure panel

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