Structural Optimization 2025 - Project #2

Description: Design the minimum volume stiffened steel panel located in the bottom of an underwater measurement station according to the image below in terms of the plate thickness t_p and the height of stiffeners h_s. The station is anchored at $10\ \mathrm{m}$ sea depth and exposed to the hydrostatic pressure. Use the response surface methodology to generate the surrogate model of the displacement and von Mises stress constraints. The allowed displacement of the panel measured in the direction of the hydrostatic load is $3\ \mathrm{mm}$. The allowed von Mises stress is $150\ \mathrm{MPa}$. Assume the sea water density of $1000\ \mathrm{kg/m^3}$ and the acceleration of gravity $g = 10\ \mathrm{m}/s^2$.

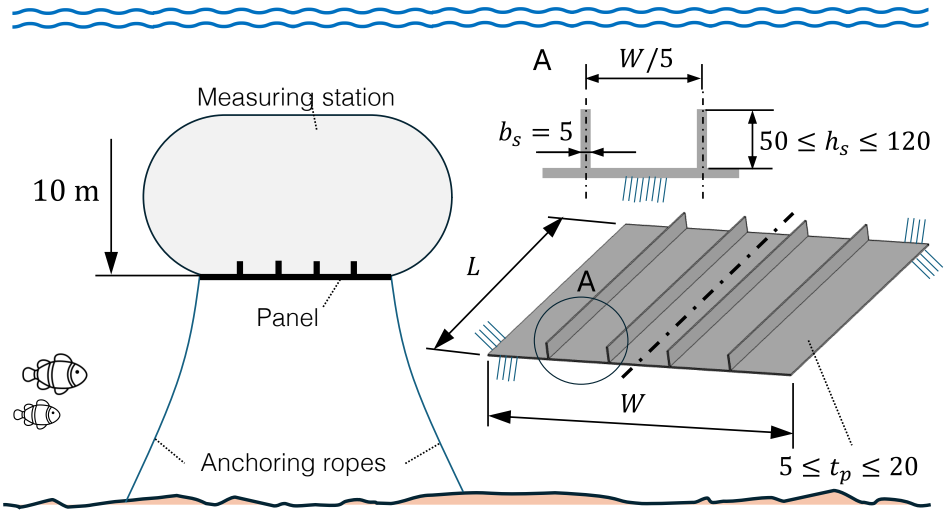

Figure 1. The panel is located at 10 m sea depth and exposed to the hydrostatic pressure.

The length L and width W of the panel are $L \times W = 1000\ \mathrm{mm} \times 1000\ \mathrm{mm}$. The panel consists of a plate p with thickness $5 \le t_p \le 20\ [\mathrm{mm}]$, and four stiffeners s with breadth $b_s = 5\ \mathrm{mm}$ and equal height $50 \le h_s \le 120\ [\mathrm{mm}]$ according to the image above. The stiffeners are distributed equally spaced alongside the plate by $W/5$ measured according to their centrelines. The panel is fixed along the edges of the plate's face exposed to the water. The Young' modulus for steel is $E = 210\ \mathrm{GPa}$.

Required libraries and templates: MATLAB version 2024b. MATLAB Partial Differential Equation Toolbox and MATLAB Optimization Toolbox. The project hand-in template is available on Moodle for download.

Tasks:

1. Calculate and report the volume of the panel, the largest displacement in the direction of the hydrostatic pressure and the largest von Mises stress for $t_p = 20$ mm and $h_s = 60$ mm. To obtain the structural response use the MATLAB Partial Differential Equation Toolbox to model the panel using tetrahedral quadratic FE elements. To facilitate the

meshing procedure set the largest and the smallest allowed sizes of FE elements to $H_{\max} = 20$ and $H_{\min} = 2.5$. Display the displacement field and the von Mises stress distribution for the panel.

2. Use the full-factorial design of experiments with two variables and five levels per each variable to sample points for the surrogate model generation. Report a table with the sampled points and the corresponding values for the largest displacement of the panel in the direction of the hydrostatic pressure and the largest von Mises stress occurring in the panel.

3. Based on the full-factorial design of experiments and the sampled points, design the second-order polynomial regression based surrogate models including cross-terms (interaction terms) for the largest displacement in the direction of the hydrostatic pressure and the largest von Mises stress in the panel. Report the values for the largest displacement and the largest von Mises stress for $t_p = 10$ mm and $h_s = 90$ for the surrogate model and the original response.

4. Use the surrogate models of the displacement and the von Mises stress responses to design the minimum volume stiffened steel panel in terms of the plate thickness t_p and the height of stiffeners h_s subject to the displacement and stress constraints. The allowed displacement of the panel measured in the direction of the hydrostatic load is $3\ \mathrm{mm}$ and the allowed von Mises stress is $150\ \mathrm{MPa}$. The starting point for the optimization is $t_p = 5$ mm and $h_s = 50$ mm. The design variables are bounded as $5 \leq t_p \leq 20\ [\mathrm{mm}]$ and $50 \leq h_s \leq 120\ [\mathrm{mm}]$. Use the interior-point method in MATLAB to optimize the panel and report the best volume with corresponding variables, and the values of constraints including both the surrogates and the originals at the optimum point.

Bonus Task: What would you do to improve the surrogate model to obtain better results? Explain your strategy and propose a pseudo-code of your approach.

Deliverables and how to submit: Write a one-page report comprising the reported values as required in Tasks 1-4, and Bonus Task if applicable. Group the one-page report and all MATLAB files relevant for each task in corresponding folders Report, Task_1, Task_2, Task_3, Task_4 and Bonus_Task folder if applicable. Compress all folders in one file and submit using the Project#2 task submission on Moodle.

Submission deadline: 11:59PM, 07.05.2025

Important information: To receive the ECTS credits for the course, it is required that an overall passing grade is obtained after submitting each of the three projects, which are to be completed individually. Each project consists of four tasks, Tasks 1-4, worth 25 Points each. The total number of points per project is 100. Each project has one additional Bonus Task worth 100 points and graded separately to the Tasks 1-4. If a passing grade is obtained over all three Bonus Tasks, a final grade bonus of 0.5 is awarded.