Project
Engineering Optimization

Part #1: Design of Pressure Vessel

A cylindrical vessel is capped at both ends by hemispherical heads as shown in Figure 1. The objective is to minimize the total cost, including the cost of the material, forming and welding. There are four design variables: thickness of the shell (T_s), thickness of the head (T_h), inner radius (R) and length of the cylindrical section of the vessel, not including the head (L).

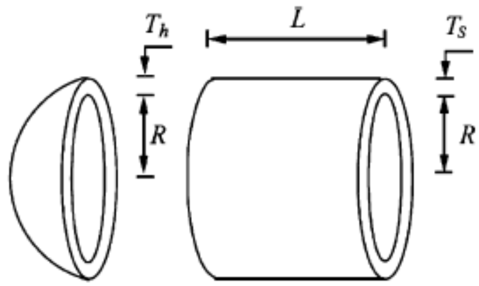

Figure 1. Pressure vessel design.

$$\begin{aligned} &Minimize\ f(R, L, T_s, T_h) \\ &\qquad = 0.6224 T_s R L + 1.7781 T_h R^2 + 3.1661 (T_s)^2 L + 19.84 (T_s)^2 R \end{aligned}$$

Subject to:

$$\begin{gathered} 0.0193R \leq T_s \\ 0.00954R \leq T_h \\ \pi R^2 L + \frac{4}{3}\pi R^3 \geq 1296000 \\ L \leq 240 \\ 0.1 \leq T_s \leq 99 \\ 0.1 \leq T_h \leq 99 \\ 10 \leq R \leq 200 \\ 10 \leq L \leq 200 \end{gathered}$$

A gradient-based optimization algorithm discussed in this course should be coded in MATLAB. Whatever method you choose, you must explain why you choose it.

- Transcribe the design problem into the standard form.
- Try different initial designs and discuss about the results.
- Verify the solution graphically and trace the history of the iterative process on the graph of the problem.

You can use ONLY MATLAB optimization tools for:

- Finding the optimal design of the transformation function in Indirect methods or;
- Finding the search direction of the subproblem in Direct methods.

Part #2: Design of Welded Beam

The objective is to design a welded beam for minimum cost. There are four design variables height of weld (*h*), length of weld (*L*), height of beam (*t*) and width of beam (*b*) as shown in Figure 2. Design is subjected to the constraints on shear stress (s), bending stress in the beam (r), buckling load on the bar (Pc), end deflection of the beam (d) and side constraints. The problem can be stated as follows:

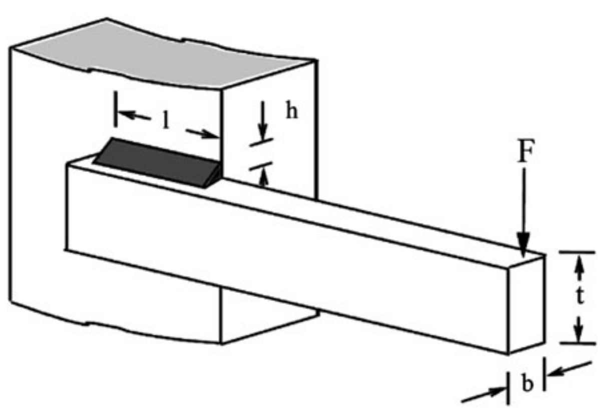

Figure 2. Welded beam design.

$$Minimize\ f(\boldsymbol{x}) = 1.10471h^2L + 0.04811\ t\ b\ (14.0 + L)$$

Subject to:

$$\tau \leq \tau_{max}$$
$$\sigma \leq \sigma_{max}$$
$$h \leq b$$
$$0.10471h^2 + 0.04811\ t\ b\ (14.0 + L) \leq 5$$
$$0.125 \leq h$$
$$\delta \leq \delta_{max}$$
$$P \leq P_c$$

where,

$$\tau = \sqrt{(\tau')^2 + 2\tau'\tau''\frac{L}{2R} + (\tau'')^2}$$
$$\tau' = \frac{P}{\sqrt{2}hL}$$
$$\tau'' = \frac{MR}{J}$$
$$M = P(W + \frac{L}{2})$$
$$R = \sqrt{\frac{L^2}{4} + \left(\frac{h+t}{2}\right)^2}$$
$$J = 2\left[\sqrt{2}hL\left\{\frac{L^2}{12} + \left(\frac{h+t}{2}\right)^2\right\}\right]$$
$$\sigma = \frac{6PW}{bt^2}$$
$$\delta = \frac{4PW^3}{Et^3b}$$
$$P_c = \frac{4.013E\sqrt{\frac{t^2b^6}{36}}}{W^2}\left(1 - \frac{t}{2W}\sqrt{\frac{E}{4G}}\right)$$

The data for the problem are given as:

$$P = 6000\ lb, \quad W = 14\ in, E = 30e^6 psi, G = 12e^6 psi, \tau_{max} = 13600\ psi,$$
$$\sigma_{max} = 30000\ psi, \delta_{max} = 0.25\ in$$

τ_{max} is the maximum shear stress of weld, τ is the weld shear stress, σ_{max} is the maximum normal stress for beam material, σ is the beam bending stress, P_c is the bar buckling load, δ is the beam end deflection, E is the modulus of elasticity for the beam material, and G is the modulus of rigidity for the beam material.

- Transcribe the design problem into the standard form.
- Write MATLAB code for Particle Swarm Optimization (PSO) and solve above constrained optimization problem.
    a. There must be a "Code Verification" section in your report so you can show why your numerical results can be trusted.
    b. Trace the best design in each iteration on the graph of the problem.
    c. Try different population size and discuss about the results.

- It is recommended that you:
    I. Use MATLAB™ to perform your calculations and perform your calculations via M-Files.
    II. Submit all MATLAB™ M-Files you wrote.

- The final grade will be based on the following criteria:
    III. Structure of your report (Maximum 40 pages).
    IV. Writing quality.
    V. Clarity of drawings, graphs, and tables.
    VI. Quality of discussion and conclusions.