Engineering Design Problems

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I. Tension/Compression Spring design

Design variables: the wire diameter(d), the mean coil diameter(D), and the number of active coils(N)

Optimization objective is to minimize the weight of a tension/compression spring.

Consider	$\vec{x} = [x_1 x_2 x_3] = [dDN]$
Minimize	$f(\vec{x}) = (x_3 + 2)x_2 x_1^2$
Subject to	$g_1(\vec{x}) = 1 - \dfrac{x_2^3 x_3}{71785 x_1^4} \leq 0$
	$g_2(\vec{x}) = \dfrac{4x_2^2 - x_1 x_2}{12566(x_2 x_1^3 - x_1^4)} + \dfrac{1}{5108 x_1^2} \leq 0$
	$g_3(\vec{x}) = 1 - \dfrac{140.45 x_1}{x_2^2 x_3} \leq 0$
	$g_4(\vec{x}) = \dfrac{x_1 + x_2}{1.5} - 1 \leq 0$
Variable range	$0.05 \leq x_1 \leq 2.00$
	$0.25 \leq x_2 \leq 1.30$
	$2.00 \leq x_3 \leq 15.0$

II. Pressure Vessel Design Problem

Design variables: the thickness of the shell(T_s),the thickness of the head(T_h), the inner radius(R), the length of the vessel(L) without considering the head.

Optimization objective is to minimize the weight of total cost (material, forming and welding) of a pressure vessel. [1]

Consider	$\vec{x} = [x_1 x_2 x_3 x_4] = [T_s T_h R L]$
Minimize	$f(\vec{x}) = 0.6224 x_1 x_3 x_4 + 1.7781 x_2 x_3^2$
	$+ 3.1661 x_1^2 x_4 + 19.84 x_1^2 x_3$
Subject to	$g_1(\vec{x}) = -x_1 + 0.0193 x_3 \leq 0$
	$g_2(\vec{x}) = -x_3 + 0.00954 x_3 \leq 0$
	$g_3(\vec{x}) = -\pi x_3^2 x_4 - \dfrac{4}{3}\pi x_3^3 + 1296000 \leq 0$
	$g_4(\vec{x}) = x_4 - 240 \leq 0$
Variable range	$0 \leq x_1 \leq 99$
	$0 \leq x_2 \leq 99$
	$10 \leq x_3 \leq 200$
	$10 \leq x_4 \leq 200$

III. Welded Beam Design Problem [2]

Design variables: the length (l), height (t), thickness (b), and weld thickness (h) of the beam.

Optimization objective is to minimize the cost of manufacturing welded beams.

Consider	$\vec{x} = [x_1 x_2 x_3 x_4] = [hltb]$
Minimize	$f(\vec{x}) = 1.10471 x_1^2 x_2 + 0.04811 x_3 x_4 (14.0 + x_2)$
Subject to	$g_1(\vec{x}) = \tau(x) - \tau_{max} \leq 0$
	$g_2(\vec{x}) = \sigma(x) - \sigma_{max} \leq 0$
	$g_3(\vec{x}) = x_1 - x_4 \leq 0$
	$g_4(\vec{x}) = 0.10471 x_1^2 + 0.04811 x_3 x_4 (14.0 + x_2)$
	$- 0.5 \leq 0$
	$g_5(\vec{x}) = 0.125 - x_1 \leq 0$
	$g_6(\vec{x}) = \delta(x) - \delta_{max} \leq 0$
	$g_7(\vec{x}) = P - P_c(x) \leq 0$
Variable range	$0.1 \leq x_1 \leq 2$
	$0.1 \leq x_2 \leq 10$
	$0.1 \leq x_3 \leq 10$
	$0.1 \leq x_4 \leq 2$

where

$$\tau(x) = \sqrt{(\tau')^2 + 2\tau'\tau''\frac{x_2}{2R} + (\tau'')^2}$$
$$\tau' = \frac{P}{\sqrt{2}x_1x_2}\tau'' = \frac{MR}{J}, M = P(L + \frac{x_2}{2})$$
$$R = \sqrt{\frac{x_2^2}{4} + (\frac{x_1 + x3}{2})^2}$$
$$J = 2\{\sqrt{2}x_1x_2[\frac{x_2^2}{12} + (\frac{x_1 + x_3}{2})^2]\}$$
$$\sigma(x) = \frac{6PL}{x_4x_3^2}, \delta(x) = \frac{4PL^3}{Ex_3^3x_4}$$
$$P_c(x) = \frac{4.013E\sqrt{\frac{x_3^2x_4^6}{36}}}{L^2}(1 - \frac{x_3}{2L}\sqrt{\frac{E}{4G}})$$
$$P = 6000lb, L = 14in, E = 30 \times 10^6 psi,$$
$$G = 12 \times 10^6 psi$$
$$\tau_{max} = 13600psi, \sigma_{max} = 30000psi, \delta = 0.25in.$$

IV. Shafting Design problem

V. Speed Reducer Problem [3]

VI. Tubular Column Design Problem [4]

VII. I-Beam Problem [1]

VIII. three-bar truss design problem [1]

IX. cantilever beam design problem [1]

X. Piston Lever Design Problem [1]

XI. Corrugated Bulkhead Design Problem [1]

XII. Car side impact design problem [5]

XIII. Reinforced Concreate Beam Design Problem [1]

References

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