レポートⅠ
report Ⅰ

航空宇宙設計最適化

6/13/2022

レポート1

下記の2つの問題を3つの異なる最適化アルゴリズムで解け.

(1) the two-objective welded beam design problem

(2) the car side impact problem

また，計算結果を比較し，なぜそのような結果の違いが生じたのかを論ぜよ.

MOEA Framework, Jmetal, PlatEMOなどにあるオープンソースコードを使ってよい（もちろん，自作でもよい）

JAVA環境としては，eclipseが推奨

レポートは7月17日（日）までにITC-LMSで提出すること

https://itc-lms.ecc.u-tokyo.ac.jp

6/13/2022

Report #1

Solve (1) the two-objective welded beam design problem and (2) the car side impact problem using three optimization algorithms.

Compare the results and discuss why the difference in the results appears.

You may use the open source codes such as MOEA Framework, Jmetal, or PlatEMO. (Off course, you may develop your own code)

For JAVA environment, “eclipse” is recommended.

The report should be submitted to Department Office by **July 17 (Sun)**

On ITC-LMS

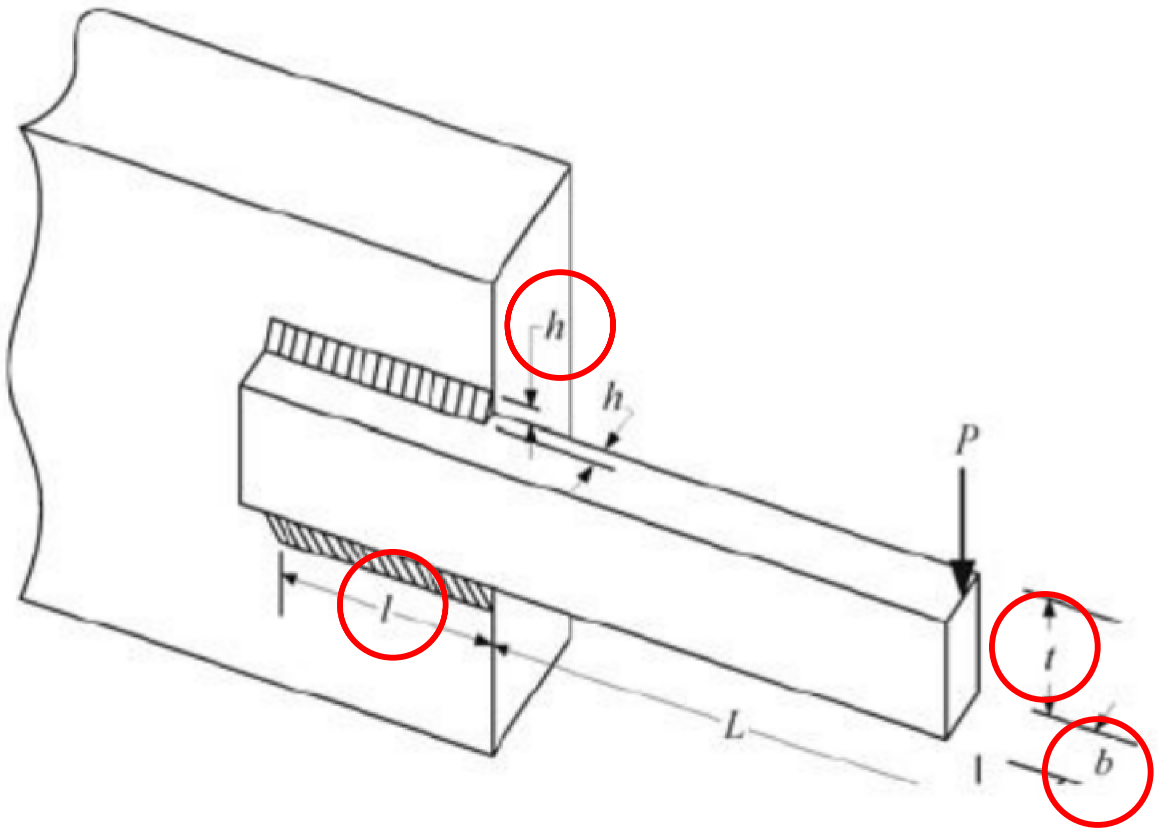
https://itc-lms.ecc.u-tokyo.ac.jp

Welded beam design problem

Objective functions : cost and end deflection (to be minimized)

Constraints : 1. shear stress, 2. bending stress, and 3. buckling load.

Design variables : h, l, t, and b



Wenyin Gong · Zhihua Cai · Li Zhu, “An Efficient Multiobjective Differential Evolution Algorithm for Engineering Design”
https://pdfs.semanticscholar.org/0841/044f92a047ae4b6b6f5dce1b9049b0006505.pdf

Welded beam design problem

minimize

$$\begin{cases} f_1(\boldsymbol{x}) = 1.10471h^2 l + 0.04811tb(14.0 + t) \\ f_2(\boldsymbol{x}) = \delta(\boldsymbol{x}) = 2.1952/(t^3 b) \end{cases}$$

subject to

$$\begin{cases} e_1(\boldsymbol{x}) = 13,600 - \tau(\boldsymbol{x}) \geq 0 \\ e_2(\boldsymbol{x}) = 30,000 - \sigma(\boldsymbol{x}) \geq 0 \\ e_3(\boldsymbol{x}) = b - h \geq 0 \\ e_4(\boldsymbol{x}) = \mathrm{Pc}(\boldsymbol{x}) - 6,000 \geq 0 \end{cases}$$

where

$$\begin{cases} \tau(\boldsymbol{x}) = \sqrt{(\tau')^2 + (\tau'')^2 + \frac{l\tau'\tau''}{\sqrt{0.25(l^2+(h+t)^2)}}} \\ \tau' = 6,000/(\sqrt{2}hl) \\ \tau'' = \frac{6,000(14.0+0.5l)\sqrt{0.25(l^2+(h+t)^2)}}{2[0.707hl(l^2/12+0.25(l^2+(h+t)^2))]} \\ \sigma(\boldsymbol{x}) = 504,000/(t^2 b) \\ \mathrm{Pc}(\boldsymbol{x}) = 64,764.022(1 - 0.0282346t)tb^3 \\ 0.125 \leq h, b \leq 5.0, \text{and} 0.1 \leq l, t \leq 10.0 \end{cases}$$

5.0

Welded beam design problem

Minimize $f_1(\boldsymbol{x}) = 1.10471x_1^2x_2 + 0.04811x_3x_4(14.0 + x_2)$

Minimize $f_2(\boldsymbol{x}) = \delta(x)$

Subject to

$$\tau(\mathbf{x}) - \tau_{\max} \le 0$$

$$\sigma(\mathbf{x}) - \sigma_{\max} \le 0$$

$$x_1 - x_4 \le 0$$

$$0.125 - x_1 \le 0$$

$$P - P_C(x) \le 0$$

where $\tau(\boldsymbol{x}) = \sqrt{(\tau')^2 + \dfrac{2\tau'\tau''x_2}{2R} + (\tau'')^2}$

$$\tau' = \frac{P}{\sqrt{2}x_1x_2}$$

$$\tau'' = \frac{MR}{J}$$

$$M = P(L + \frac{x_2}{2})$$

$$R = \sqrt{\frac{x_2^{\,2}}{4} + \left(\frac{x_1 + x_3}{2}\right)^2}$$

$$J = 2\left\{\sqrt{2}x_1x_2\left[\frac{x_2^{\,2}}{12} + \left(\frac{x_1 + x_3}{2}\right)^2\right]\right\}$$

$$\sigma(\boldsymbol{x}) = \frac{6PL}{x_4x_3^{\,2}}$$

$$\delta(\boldsymbol{x}) = \frac{4PL^3}{Ex_4x_3^{\,3}}$$

$$P_C(\boldsymbol{x}) = \frac{4.013E\sqrt{\dfrac{x_3^{\,2}x_4^{\,6}}{36}}}{L^2}\left(1 - \frac{x_3}{2L}\sqrt{\frac{E}{4G}}\right)$$

P = 6000 lb, L = 14 in, δ_{max} = 0.25 in, E = 30 × 10^6 psi, G = 12 × 10^6 psi, τ_{max} = 13,600 psi, σ_{max} = 30,000 psi, 0.125 ≤ x_1 ≤ 5.0, 0.1 ≤ x_2 ≤ 10.0, 0.1 ≤ x_3 ≤ 10 and 0.125 ≤ x_4 ≤ 5.0

Car side impact problem

- Objective functions : 1. minimization of weight of car,
  2. minimization of pubic force experienced by a passenger,
  and 3. average velocity of the V-Pillar
- Constraints : 10 constraints limiting values of abdomen load, pubic force, velocity of V-Pillar, rib deflection, etc.
- Design variables : 11 design variables describing thickness of B-Pillars, floor, cross-members, door beam, roof rail, etc.

Himanshu Jain and Kalyanmoy Deb, “An Evolutionary Many-Objective Optimization Algorithm Using Reference-point Based Non-dominated Sorting Approach, Part II: Handling Constraints and Extending to an Adaptive Approach”
https://www.egr.msu.edu/~kdeb/papers/k2012010.pdf

Car side impact problem

$$
\begin{aligned}
f_1(\mathbf{x}) =& 1.98 + 4.9x_1 + 6.67x_2 + 6.98x_3 + 4.01x_4 + 1.78x_5 \\
& + 0.00001x_6 + 2.73x_7, \\
f_2(\mathbf{x}) =& F \\
f_3(\mathbf{x}) =& 0.5(V_{MBP} + V_{FD}) \\
g_1(\mathbf{x}) =& 1.16 - 0.3717x_2x_4 - 0.0092928x_3 \leq 1 \\
g_2(\mathbf{x}) =& 0.261 - 0.0159x_1x_2 - 0.06486x_1 - 0.019x_2x_7 + 0.0144x_3x_5 \\
& + 0.0154464x_6 \leq 0.32 \\
g_3(\mathbf{x}) =& 0.214 + 0.00817x_5 - 0.045195x_1 - 0.0135168x_1 \\
& + 0.03099x_2x_6 - 0.018x_2x_7 + 0.007176x_3 \\
& + 0.023232x_3 - 0.00364x_5x_6 - 0.018x_2^2 \leq 0.32 \\
g_4(\mathbf{x}) =& 0.74 - 0.61x_2 - 0.031296x_3 - 0.031872x_7 + 0.227x_2^2 \leq 0.32 \\
g_5(\mathbf{x}) =& 28.98 + 3.818x_3 - 4.2x_1x_2 + 1.27296x_6 - 2.68065x_7 \leq 32 \\
g_6(\mathbf{x}) =& 33.86 + 2.95x_3 - 5.057x_1x_2 - 3.795x_2 - 3.4431x_7 \\
& + 1.45728 \leq 32 \\
g_7(\mathbf{x}) =& 46.36 - 9.9x_2 - 4.4505x_1 \leq 32 \\
g_8(\mathbf{x}) \equiv& F = 4.72 - 0.5x_4 - 0.19x_2x_3 \leq 4 \\
g_9(\mathbf{x}) \equiv& V_{MBP} = 10.58 - 0.674x_1x_2 - 0.67275x_2 \leq 9.9 \\
g_{10}(\mathbf{x}) \equiv& V_{FD} = 16.45 - 0.489x_3x_7 - 0.843x_5x_6 \leq 15.7
\end{aligned}
$$

Car side impact problem

Variable bounds are given given as follows:

$$
\begin{array}{lll}
0.5 \leq x_1 \leq 1.5, & 0.45 \leq x_2 \leq 1.35, & 0.5 \leq x_3 \leq 1.5, \\
0.5 \leq x_4 \leq 1.5, & 0.875 \leq x_5 \leq 2.625, & 0.4 \leq x_6 \leq 1.2, \\
0.4 \leq x_7 \leq 1.2 & &
\end{array}
$$