ME46060 “Engineering Optimization – Concepts and Applications” Exercise 6

Subject: “Valve spring”

Objectives

- Use SQP (fmincon) to solve constrained optimization problem.

Course material

- Section 5.5 and Section 6.7 of Papalambros and Wilde [1]

Introduction

Consider the following constrained optimization problem of the valve spring:

Minimize f(**x**) = smass (spring mass)

Subject to:

L2 ≥ Lmin
F1 ≥ F1min
F2 ≥ F2min
Tau2 ≤ Tau12max (= 600e+6 N/m^2)
freq1 ≥ freq1lb
Set constraint:
0.02 ≤ x(1) ≤ 0.04 (m)
0.002 ≤ x(2) ≤ 0.005 (m)

This problem is similar as in exercise 2 and 5, except some modifications of the input parameters (now given in the file springparams2.m). Row vector **x** represents the design variables, being the coil diameter D (= x(1)) and the wire diameter d (= x(2)) respectively.
The problem is visualized by running the (given) program springw6ex1, using the files springobj2.m (mass objective function) and springcon2.m (constraints).

Exercise 6.1: Visualization of constrained spring optimization problem.

Look springw6ex1.m and see how the visualization is realized. Run springw6ex1.m and indicate (by hand) the objective function, constraints and the feasible domain resulting Figure 1. Note that the dotted contours lie in the infeasible region. Estimate the expected optimum.

Exercise 6.2: Constrained optimization by SQP.

Extend the file springw6ex1.m to springw6ex2.m in order to solve the problem mentioned above using the SQP algorithm fmincon of MATLAB, and the given files springobj2.m and springcon2.m. Note that the file springcon2.m has to be modified a little to incorporate the (empty) vector of equality constraints (name the modified file springcon3.m). Do **not** provide the gradients of the objective function and the constraints by means of a MATLAB-function. Question: how does the fmincon algorithm compute the mentioned gradients in that situation?

Use the point x0 (= [D d]) = [0.034   0.0045] as initial design point. Solve the problem for the output parameters [x, fval, exitflag, output, lambda]. Give also output of the constraint values. Plot a marker in the initial point and in the final solution point.

Interpret the results [x, fval, exitflag, output, lambda], and the constraints; check whether the used convergence criteria are satisfied. Which constraints are active? Check the Lagrange multipliers with respect to constraint activity.

Also try some other initial design points.

References

[1] Papalambros, P.Y. and Wilde, D.J., *Principles of optimal design: modeling and computation*, 3rd edition, Cambridge University Press, 2017.