ME46060 “Engineering Optimization – Concepts and Applications” Exercise 2

Subject: “Valve spring”,

Objectives:

- Study the behavior of model functions, and learn how to recognize monotonicity, (non-)convexity and (non-)linearity.
- Identify properties of optimization problems including dominance, activity, well boundedness, and convexity.

Introduction

Consider a compression spring involving two design variables: **D** (mean winding diameter) and **d** (wire diameter). All other design parameters are assumed constant as given in the .m-file **springparams1.m.**

Exercise 2.1: Model function behavior.

Run the program given as .m-file **springanalysis2.m** to visualize the functional behavior of the axial spring stiffness **k** as function of the design variables **D** and **d**. Study the program **springanalysis2.m** and see how the visualization is programmed. Note that in **springanalysis2.m** the function **springanalysis1.m** (given in week 1) is called to analyze the spring.

Interprete the results, and add the option `'showtext', 'on'` to the `contour` command to show the levels of the spring stiffness contours in the plot. What can you say about monotonicity, convexity and (non-)linearity of the spring stiffness **k** as function of **D** and **d**?

Modify **springanalysis2.m** appropriately in order to repeat your investigations for the output variables:

- **smass** (mass of the spring); write **springanalysis3.m**
- **freq1** (lowest eigenfrequency); write **springanalysis4.m**
- **tau2** (shear stress at fully opened valve); write **springanalysis5.m**.

Interpret the results.

Exercise 2.2: Model transformations/ optimization formulation

Consider the following optimization problem:

Design variables: **D** and **d**
(other design parameters are constant and given in .m-file **springparams1.m**)
Minimize **smass**
Constraints:

L2 ≥ Lmin
F1 ≥ F1min
F2 ≥ F2min
Tau2 ≤ Tau12max
freq1 ≥ freq1lb

Set constraints:

$0.02 \leq D \leq 0.04$
$0.002 \leq d \leq 0.005$

Use as maximum allowable shear stress the (for this moment) fixed value **Tau12max = 600*10^6 N/m^2.** How should the limit value for the lowest eigenfrequency (=**freq1lb**) be calculated?

Transform the optimization problem to the **negative null form**. Apply scaling of the constraints; leave the objective function unscaled.

Write a .m-file, named **springopt1.m,** to compute objective function and constraint functions, and to plot (visualize) the transformed and scaled optimization problem. Indicate constraint names by hand in the plot.

Hints:

- As example of visualization see the .m-file **springanalysis2.m**
- Using the MATLAB function **contour** to plot a single level of a certain constraint you must plot the contour line twice, see MATLAB-help “contour”. For example, to plot the constraint gi at level zero you should use the statement:
  ```
  contour(D, d, gi, [0.0  0.0])
  ```
- To identify which side of a constraint boundary belongs to the feasible region, you can add an additional contour line at a level >0, using a different line style, e.g. ‘--‘ (dashed):
  ```
  contour(D, d, gi, [1.0  1.0], '--')
  ```