Design of helical springs

DME3350

GitHub Repository - https://github.com/AakashSYadav/DME

1.1. Aim

To automate the process of designing of helical spring

1.2. Scope

We can design a spring based on different requirements of user in maximum and minimum loads, free length, solid height and maximum compression in accordance to the failure criteria and relevant factor of safety.

1.3. Assumptions

- Stresses in the spring are proportional to load
- An element of an axially loaded helical spring behaves essentially as a straight bar in pure torsion.
- We have used the $Bergsträsser\ factor$(K_B).

2.1. Procedure

2.1.1. Static loading

- Take input as F_{Max}, maximum compression, material, factor of safety, Free and solid length
- Starting from d = 0.001 in, the iteration is started
- Depending on material and d we can find the S_{ut} and S_{Sy}
- Followed by the given calculations
  - $\alpha = S_{Sy}/n_s$ and $\beta = 8(1+\xi)F_{max}/\pi d^2$
  - $c = \frac{2\alpha-\beta}{4\beta} + \sqrt{\left(\frac{2\alpha-\beta}{4\beta}\right)^2 - \frac{3\alpha}{4\beta}}$
  - $D = c \times d$
  - $K_B = \frac{4c+2}{4c-3}$
  - $N_a = Gd^4 y_{max}/(8D^3 F_{max})$

- N_t depending on the type of end we can find N_t
- $L_s = d \times N_a$
- $L_o = L_s + (1 + \xi)y_{max}$
- $Fom = -(relative\ cost)\gamma\pi^2 d^2 N_t D/4$

- Validate the results from the following constraints:

$$4 \leq C \leq 12$$

$$3 \leq N_a \leq 15$$

$$\xi \geq 0.15$$

$$n_s \geq 1.2$$

- Show the variation of figure of merit with respect to different values for d.

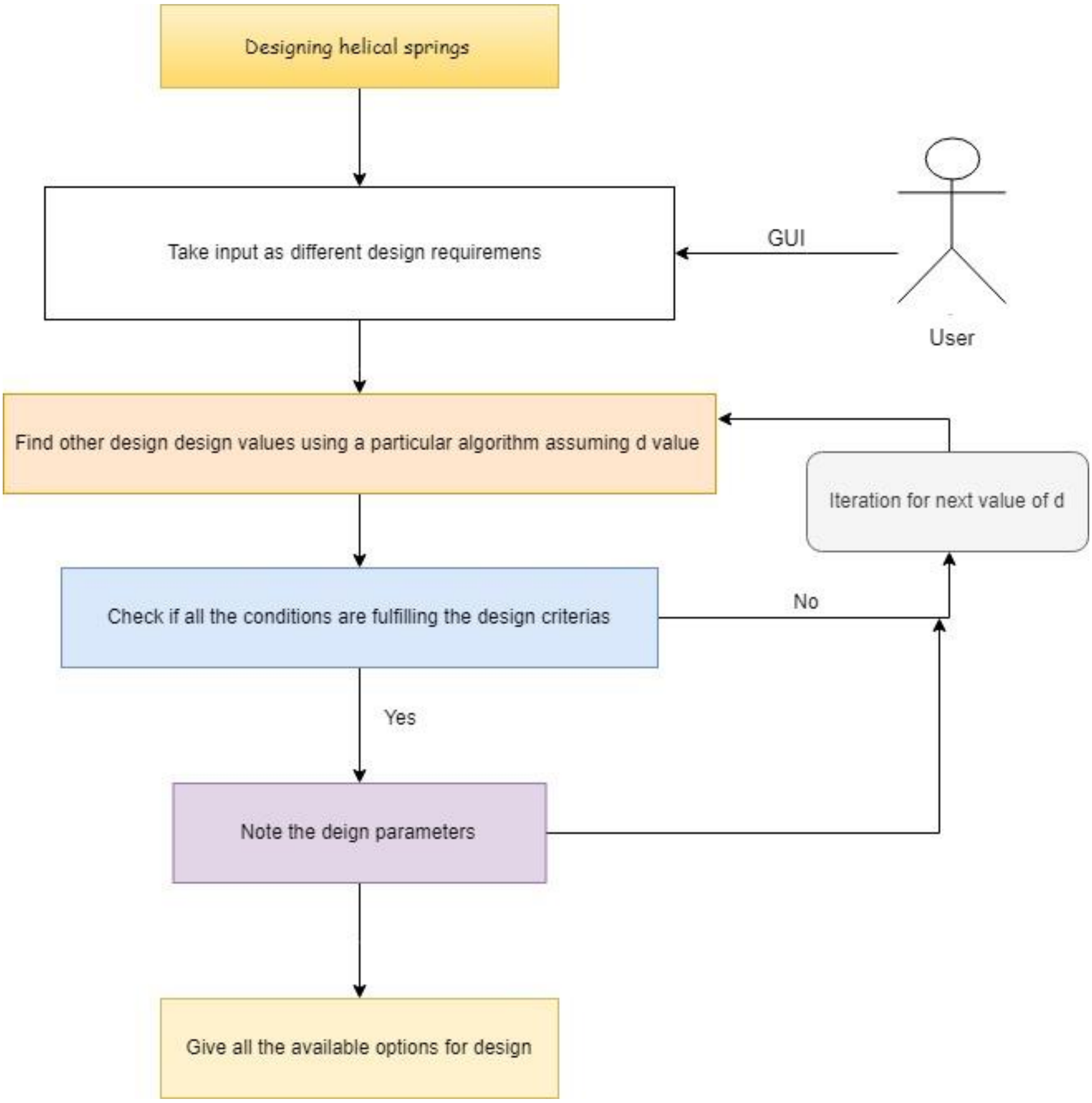
2.1.2. Dynamic loading

- Take input as F_{Max}, F_{min}, theory of failure to be followed, material, factor of safety, spring rate
- Starting from d = 0.001 in, the iteration is started
- Depending on material and d we can find the S_{ut}, S_{Sy} ,S_{Se} and S_{Su}
- According to different theories of failure we can find the different values of c.
- Solved the biquadratic equations in case of Gerber parabola and Gough ellipse using Sympy - Symbolic Mathematics in Python (a MATLAB like extension for python).
- Check if c follows the condition: $4 \leq c \leq 1$
- Followed by the given calculations
  - $D = c \times d$
  - $K_B = \frac{4c+2}{4c-3}$
  - $N_a = Gd^4/(8D^3k)$
  - N_t depending on the type of end we can find N_t
  - $L_s = d \times N_a$
  - $L_o = L_s + (1 + \xi)y_{max}$
  - $Fom = -(relative\ cost)\gamma\pi^2 d^2 N_t D/4$
- Validate the results from the following constraints:

$$3 \le N_a \le 15$$
$$\xi \ge 0.15$$
$$n_s \ge 1.2$$

- Show the variation of figure of merit with respect to different values for d.

2.2. Flowchart :



3. Validation of code with hand calculation

Part I : Constant load

Material: music wire
Maximum load: 20 lbf
y_{max}: $2in$
$L_s \leq 1\ in$
$L_o \leq 4\ in$

Let ns (Factor of safety) =1.2, d=0.08 in and $\xi = 0.15$

$$S_{ut} = \frac{201000}{0.080^{0.145}}$$

$$S_{sy} = 0.45 \times \frac{201000}{0.080^{0.145}} = 130455\, psi$$

$$\alpha = S_{Sy}/n_s = 130455/1.2 = 108\ 713 \text{ psi}$$

$$\beta = 8(1+\xi)F_{max}/\pi d^2 = 8(1\ +\ 0.15)20/\ \pi\ (0.080^2) = 9151.4 \text{ psi}$$

$$c = \frac{2\alpha - \beta}{4\beta} + \sqrt{\left(\frac{2\alpha - \beta}{4\beta}\right)^2 - \frac{3\alpha}{4\beta}} = 10.53$$

$$D = c \times d = 10.53 \times 0.080 = 0.8424$$

$$K_B = \frac{4c+2}{4c-3} = 1.128$$

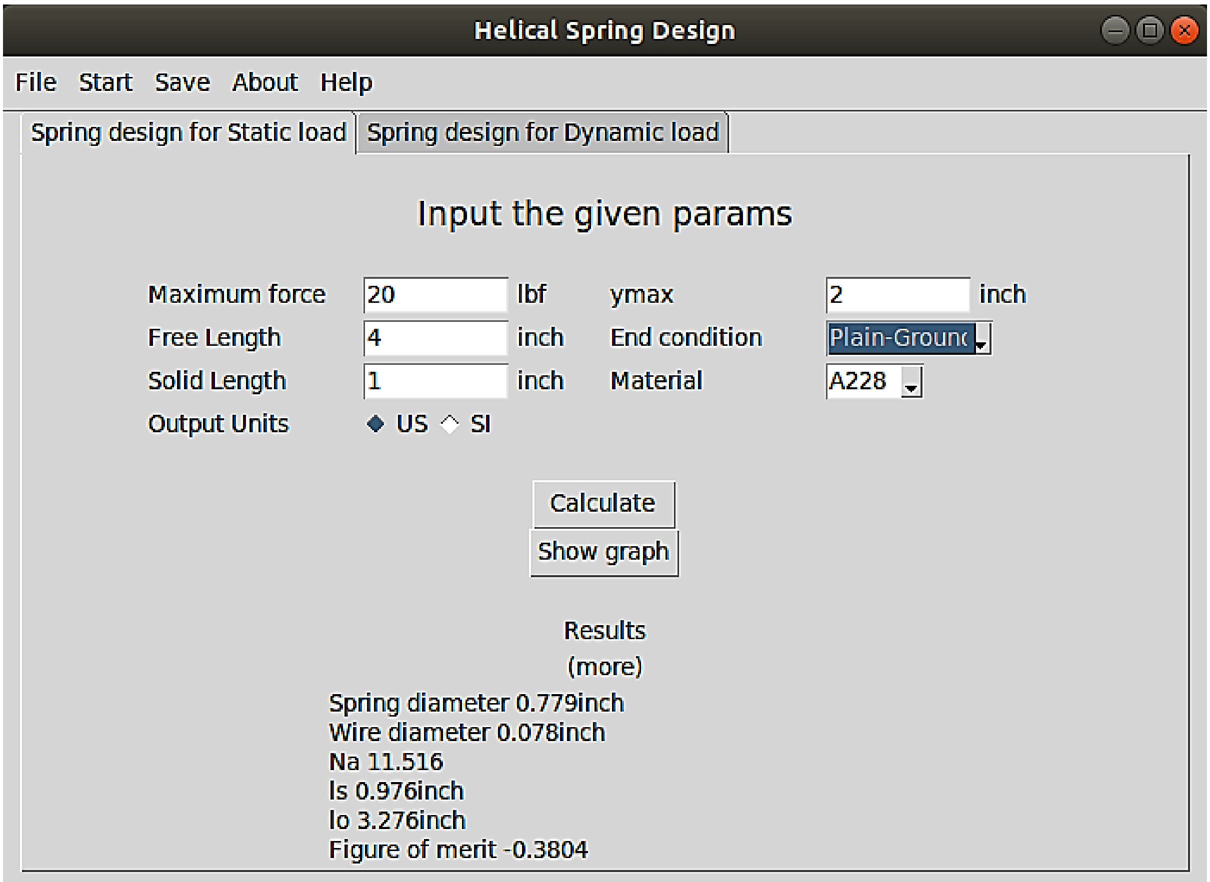
$$N_a = \frac{Gd^4 y_{max}}{(8D^3 F_{max})} = 10.05$$

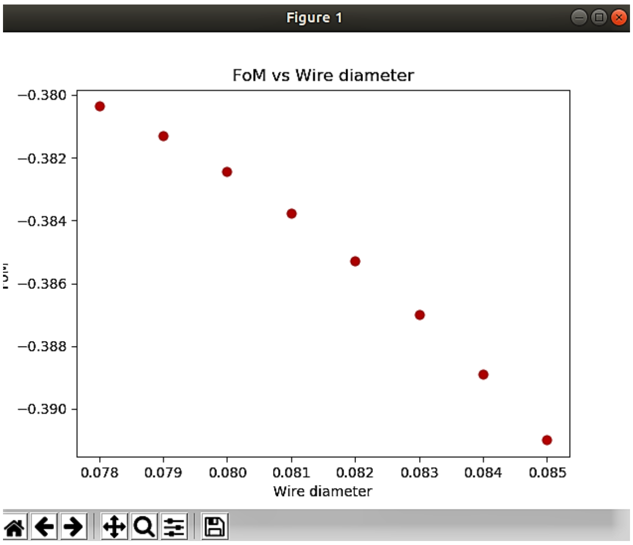
$N_t = N_a + 2$ (For square and ground ends) =12.05

$$L_s = d(N_t) = 0.080 \times 12.05 = 0.964\ in$$

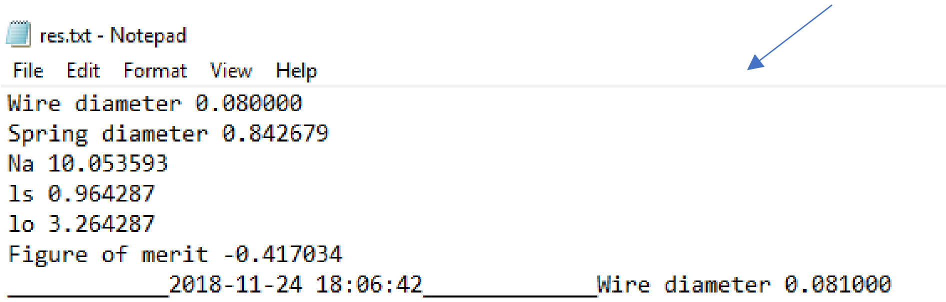
$$L_0 = L_s + (1+\xi)y_{max} = 0.964\ +\ (1\ +\ 0.15)2\ =\ 3.264 \text{ in}$$

$Fom = -\frac{(relative\ cost)\gamma\pi^2 d^2 N_t D}{4} = -0.417$ (Taking $\gamma = 1$)





For exporting the results



Part II : Varying load

Design criteria:

Material: music wire
Theory of failure: Goodman criteria

$F_{max} = 18\ lbf$

$F_{min} = 4\ lbf$

$F_m = 11\ lbf$

$F_a = 7\ lbf$

$D + d \leq 2.5\ in$

Let d = 0.0915 in

$\left(\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}}\right) = \frac{1}{n_f}$

Solving the quadratic equation, we get c_1=10.429 and c_2=0.8468

Neglecting c_2 ($4 \leq c \leq 12$)

$D = c \times d = 10.429 \times 0.0915 = 0.954\ in$

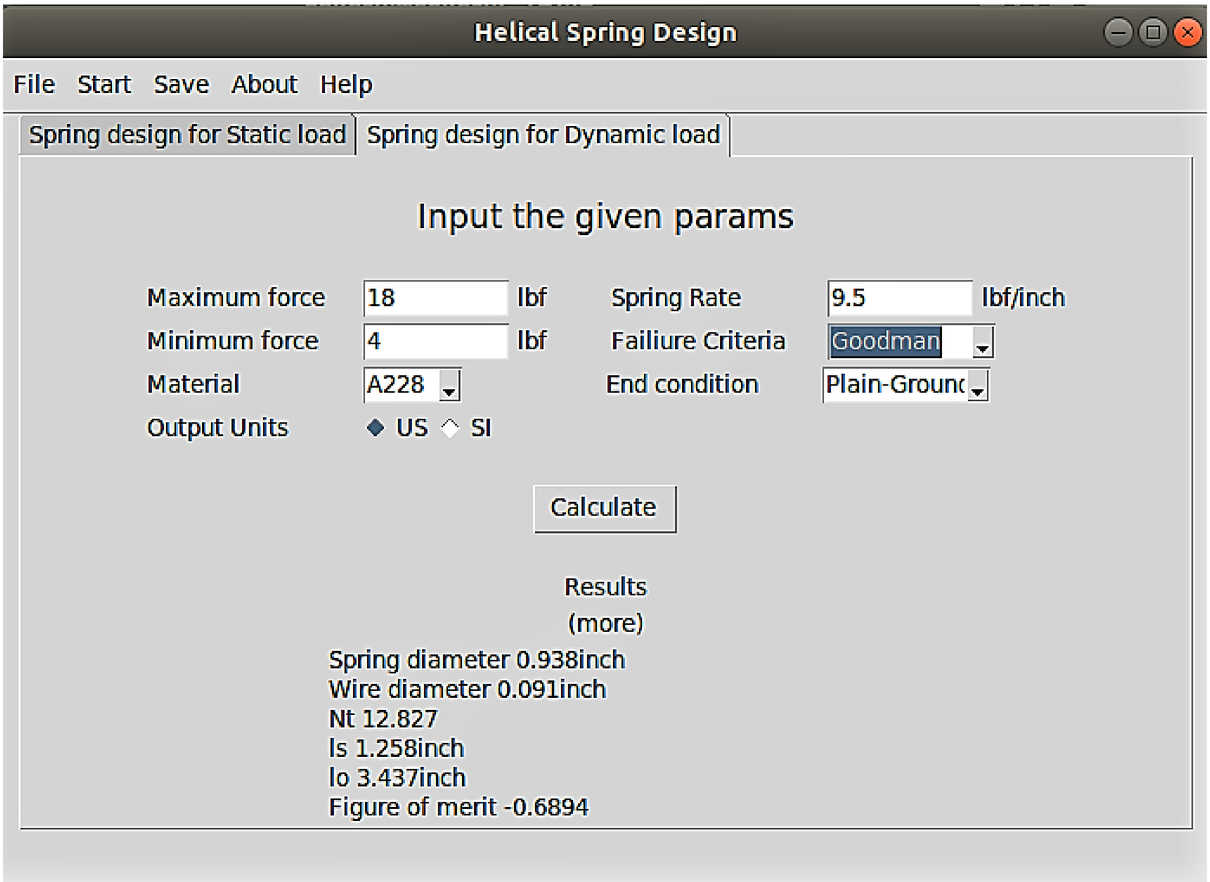
$N_a = \frac{d^4 G}{8D^3 k} = 12.481$

$N_t = N_a + 2 = 12.481 + 2 = 14.481$

$y_{max} = \frac{F_{max}}{k} = 1.8947\ in$

$L_s = N_t \times d = 1.325\ in$

$L_o = L_s + (1 + \xi)y_{max} = 3.5039\ in$



4. Applications

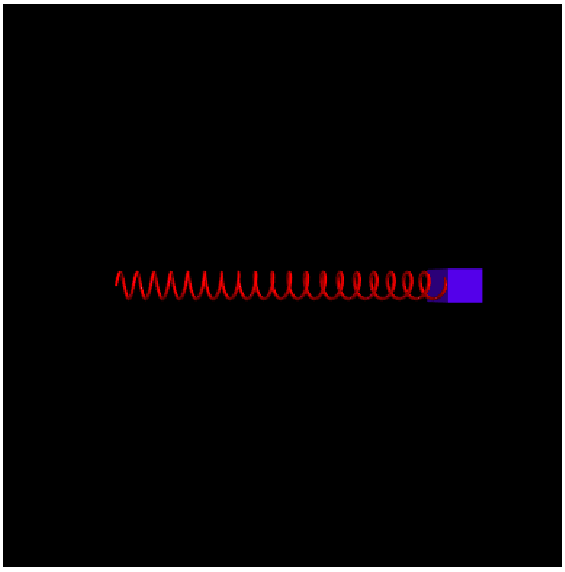
It can be used by industries as well as small manufacturers to design springs according to their requirements and select the best design of spring among all the springs available based on specific needs and figure of merit.

5. Possible future extensions

- We have designed the algorithm just for the case of helical springs, so we can use a similar algorithm to design torsion, leaf and Belleville springs.
- Addition of simulation and model of the spring and integrating it with the generated results. We are going to use visual python to show the spring as well as the interaction of spring with a specific mass under certain conditions.
- Addition of 'Export PDF' option to ease post calculation work
- Addition of 'Save' button to save a copy of the current session.

Additional

Simulated using vpython



Note: The complete project is open source and is available at https://github.com/AakashSYadav/DME. Yes, each and every line of this code has been written by us.