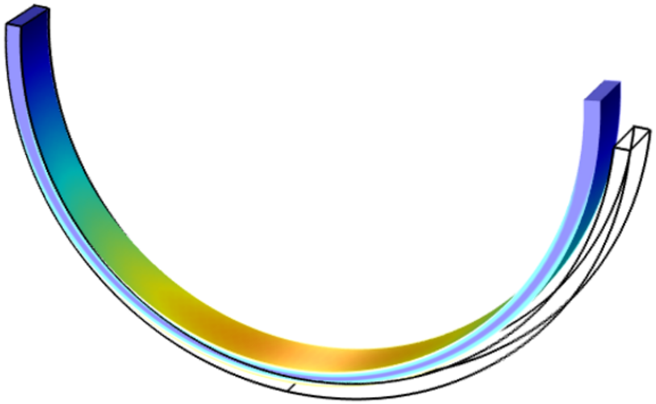
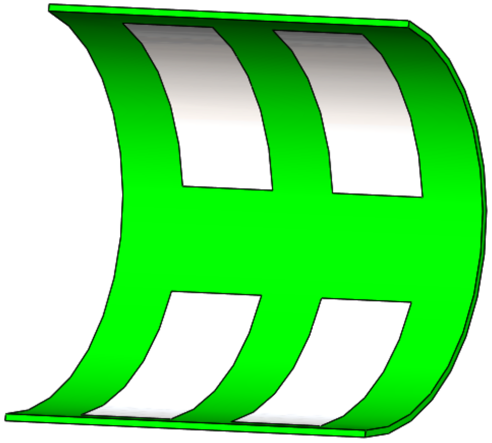
# NON-COILED SPRING OPTIMIZATION ASSISTED BY AN ANALYTICAL MODEL





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# OUTLINE

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Beam theory

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Results

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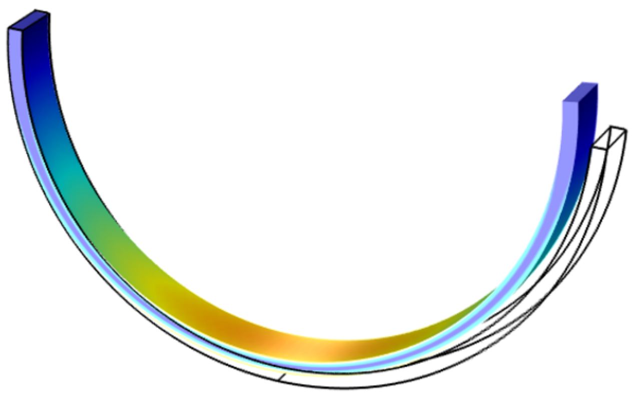
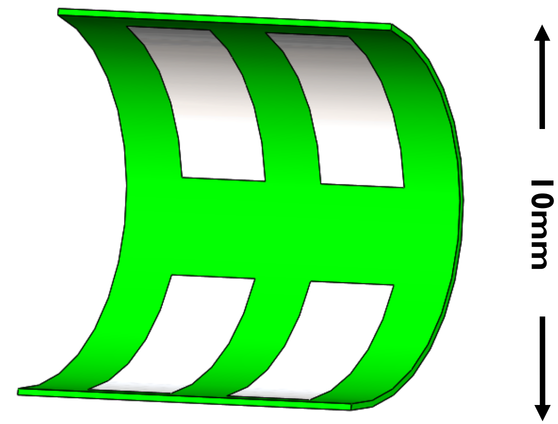
# MOTIVATION

Wiper



Potentiometer




Need to come up with an optimized spring design in term of robustness to tolerance and creep in a constrained space.

Drawbacks of conventional optimization method

1. Computationally expensive
2. Risk of trapped in local minima
3. Treated as a black box

# PROBLEM STATEMENT

**Spring wiper design requirement:**

1. Sheet metal
2. Reside in the 10mm circle
3. Being soft to be robust to tolerance
4. Maximum stress below a certain safety factor to be resistant to creep

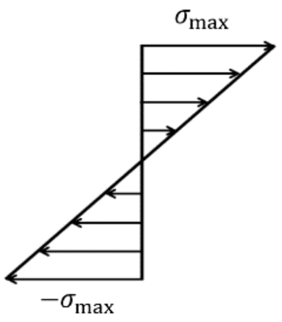
**Optimization problem:**

$$Min_{\mathrm{w,th}}: k$$
$$s.t.: \sigma_{max} < c\%\sigma_{yield} \quad at\ max.\ load$$

# BEAM THEORY

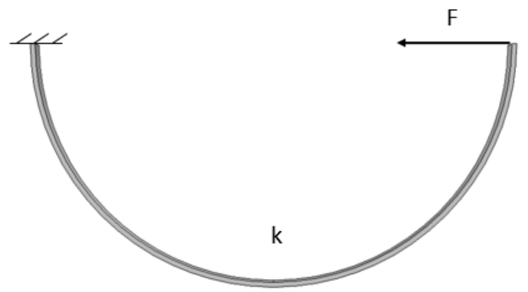
Based on beam theory, the energy stored in a deformed beam is

$$E = \iint \frac{\sigma^2}{2E} dAds$$




With work-energy theorem, the work to generate the above energy is

$$W = \frac{Fd}{2} = \frac{F^2}{2k}$$




With two equation above and the assumption that the axial geometry and load is not changed,

$$\frac{1}{2k} \propto \sigma_{max}{}^2 wt\ .$$

# BEAM THEORY

With the beam constitutive equation,

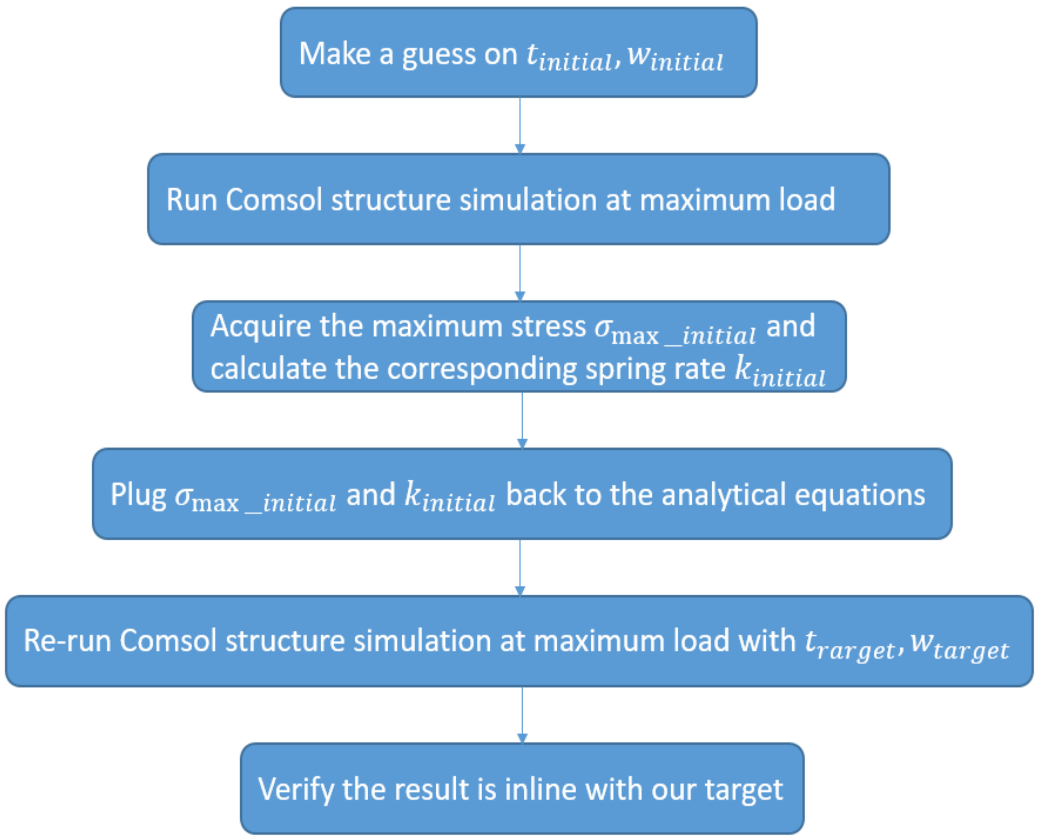
$$k \propto I \propto wt^3 .$$

With the equations above, we can derive

$$t_{target} = \frac{sf\sigma_{yield}k_{target}}{\sigma_{max\_initial}\,k_{initial}}\,t_{initial} ,$$

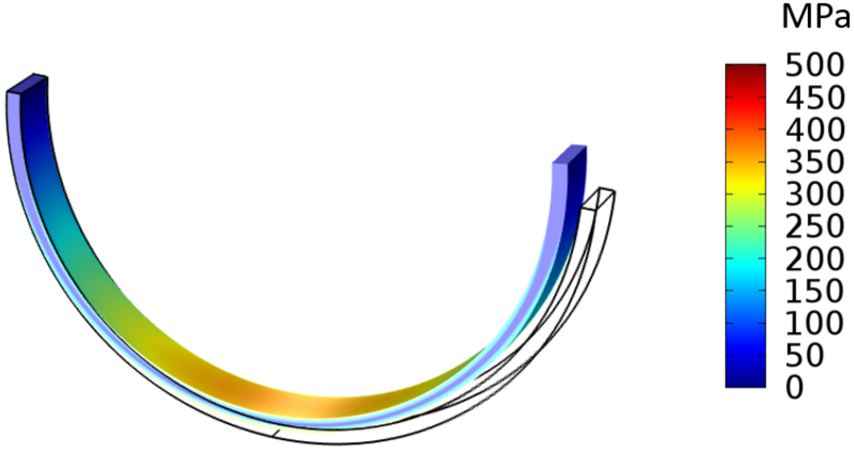
$$w_{target} = \frac{\sigma_{max\_initial}{}^{3}k_{initial}{}^{2}}{(\sigma_{target})^{3}k_{target}{}^{2}}\,w_{initial} .$$

# TREATMENT/APPROACH

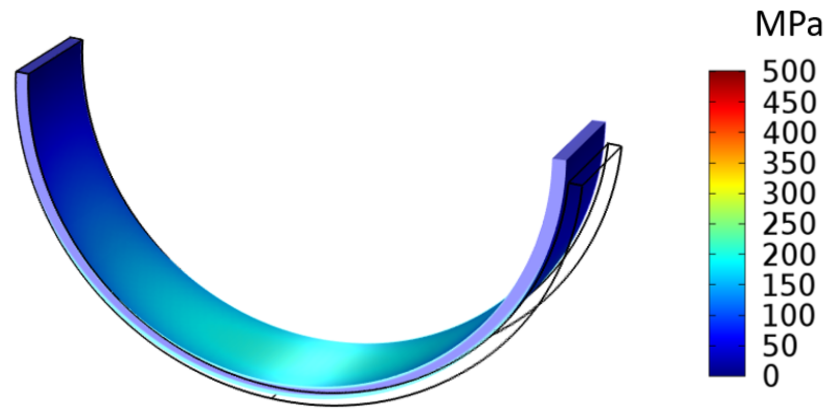


# RESULTS

Iteration 1

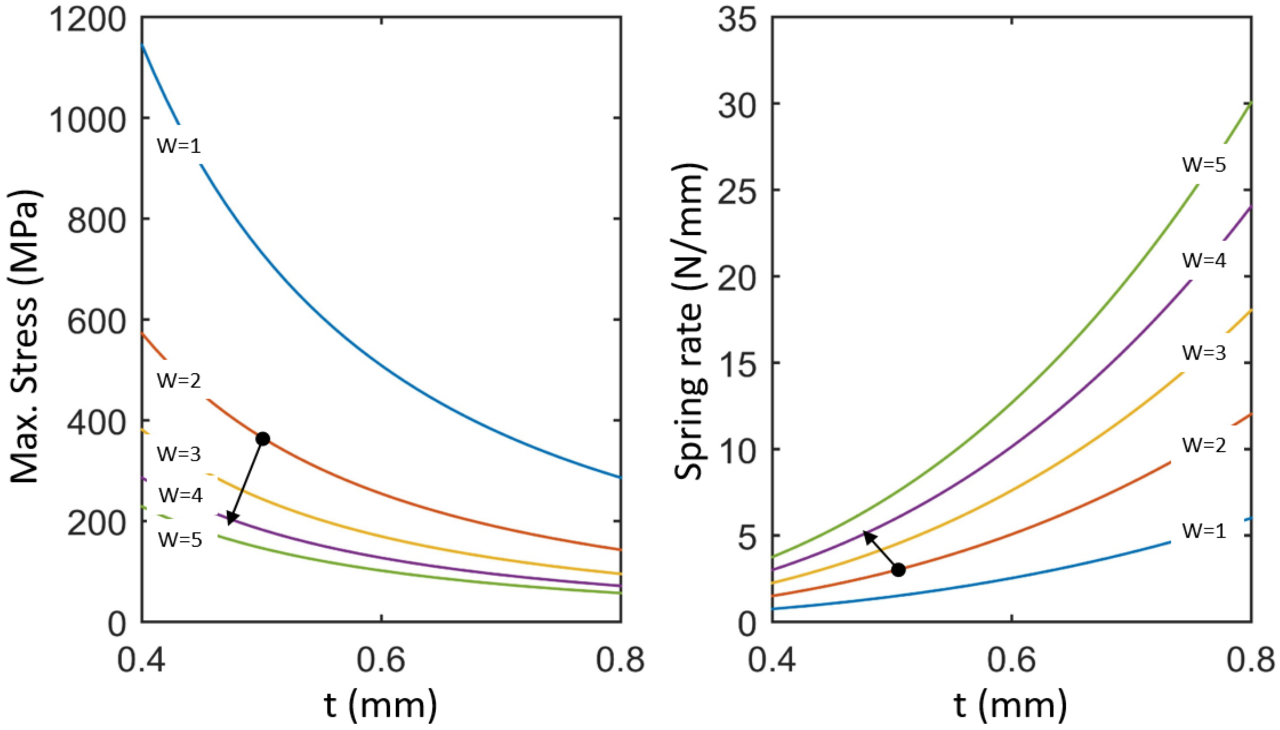



Iteration 2




| | Spring rate (N/mm) | Max. stress (MPa) | Thickness (mm) | Width (mm) |
|---|---|---|---|---|
| **Target** | 5 | 200 | | |
| **Iteration 1** | 2.936 | 366 | 0.5 | 2 |
| **Iteration 2** | 5.045 | 212 | 0.465 | 4.234 |

# DESIGN VARIABLES SPACE




Spring performance w.r.t. design variable space.
The arrow represents the optimization trajectory in previous Table

# SUMMARY

- Proposed a time efficient approach to optimize the characteristics of a non-coiled spring to the desired spring rate and maximum strength.
- Performed structure simulations in COMSOL with the analytical model assisting the optimization.
- Showed one application of this approach to illustrate how this approach benefits our engineering practice.
- Quality of results is examined.