Homework 4

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I. RESULTS

A. Single Load Level

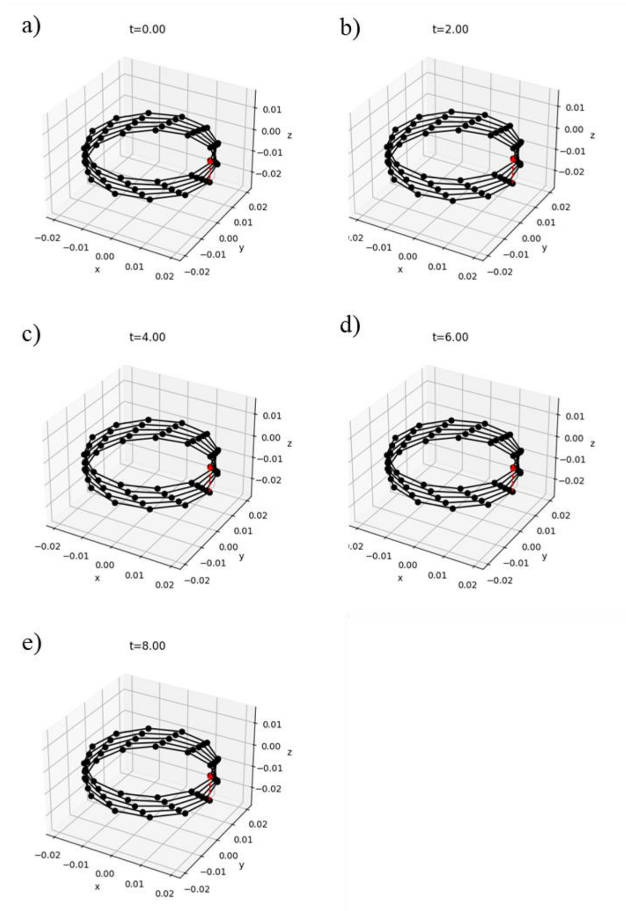

Figure 1: Shown are the helix at different simulation times $t = \{0, 3, 6, 9, 12, 15, 17\}$ with $F = 2 \times 10^{-5} N$.

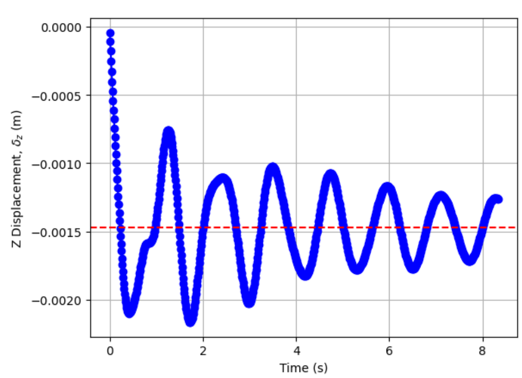

Figure 2: Shown is the displacement (δ_z) of helix over time, and the dashed red line is steady-state displacement ($\delta_z^* = -0.00147\ m$).

To check if the system reached the steady state, 6-second period of displacement values before a certain simulation time step were considered. When the absolute difference between the average displacement of the first 3-second and the last 3-second is smaller than 0.1% of the 6-second displacement average, the system is defined as stable.

B. Force Sweep and Linear Fitting

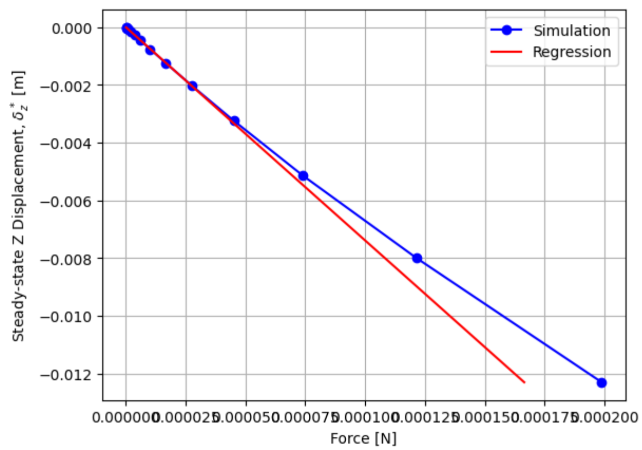

Figure 3: Shown is steady-state displacement over force. The red line is the regression result of small force region ($k = 0.0135$ N/m).

If the steady-state displacement ($\boldsymbol{\delta}$) and force ($\boldsymbol{F}$) are column vectors. Then, the linear stiffness (k) can be solved by

$$k = (\boldsymbol{\delta}^{\boldsymbol{T}}\boldsymbol{\delta})^{-1}\boldsymbol{\delta}^{\boldsymbol{T}}\boldsymbol{F} \quad (1)$$

In this example, the theoretical linear stiffness is

$$k_{text} = \frac{Gd^4}{8ND^3} \approx 0.0208 \quad (2)$$

Where G is sheer modulus, d is wire diameter, D is coil diameter, and N is number of turns.

C. Diameter Sweep and Theoretical Trend

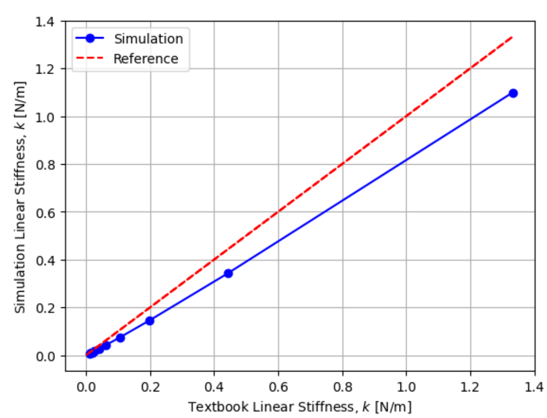

Figure 4: Shown is simulation stiffness vs. textbook prediction with the slope-1 reference.

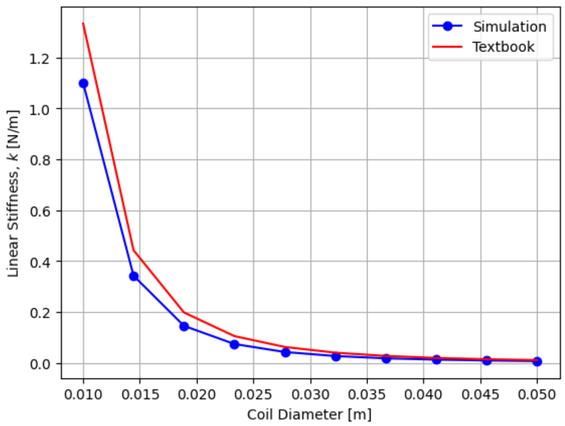

Figure 5: Shown is the simulation and textbook stiffness with respect to different coil diameters.

For all coil diameters, theoretical stiffness is higher than simulation, which means as the diameters increases, in reality (simulation), the stiffness of coil doesn't decay as fast as textbook prediction. However, both results share the same trend: as helix diameter increases, the stiffness will decrease.