School of Physical and Mathematical Sciences

Using PyElastica to Explore the Effects of Forces on Cosserat Rods

Lim Zi Yao, Yong Ee Hou

Introduction

Elastic rods are a constant focus of study across multiple fields due to its abundancy in both the natural and artificial world, and can be described in a simplistic manner by the Cosserat Rod Theory, which assumes the rod to be 1-d, slender, and capable of being bent, twisted, stretched and sheared. This study aims to use PyElastica, a open-source software created by Gazzola Labs, to make some simple explorations of the effects of forces on Cosserat Rods.

Methodology

After setting up basic parameters for the rod, data of a sample rod with one end fixed and with a downward force acting at its free end only was recorded for comparison purposes. A video of the simulation was also created. It was observed that the rod initially bends downwards, comes to a halt, and starts to oscillate. All following simulations will be based on this rod and its parameters.

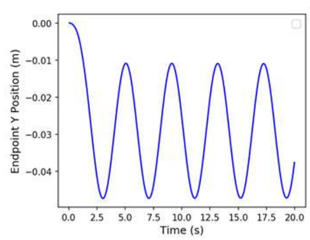

Figure 1: Plot of the Y position of the rod's free end against time

1. Changing the force ramp up time

During the process, it was noticed that at certain values of the ramp up time, the rod did not oscillate after it reaches the threshold value and stays in place.

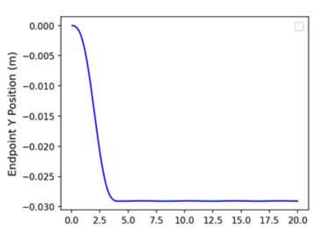

Figure 2a

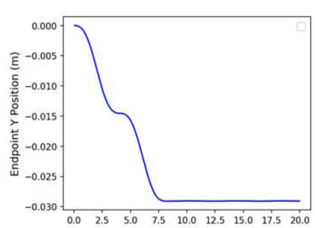

Figure 2b

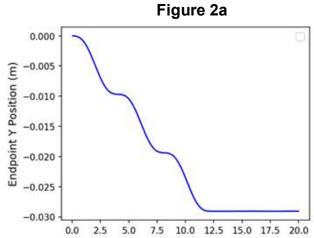

Figure 2c

Figure 2: Plot of the Y position of the rod's free end against time when ramp up time equals to: a, 4.07s; b, 8.12; and c, 12.19.

The number of halts the rod makes before it enters the oscillation region in the graph will increase by one per step of the period. It was also discovered that the period can be changed and shifted by changing Young's Modulus. The evolution of internal stress of the rod remains unchanged throughout the changes in ramp up time, approaching a constant, also unchanged value near the end of the simulation runtime.

2. Changing the torque

It was observed that after applying a right-handed torque on the free end of the rod along the same axis, the amplitude of the damping torque, which reflects the torsion, increases linearly with respect to the increase in the magnitude of torque. The shape of the graph remains unchanged and only changes in amplitude except when torque equals to 0, where the pattern is just a straight line at 0.

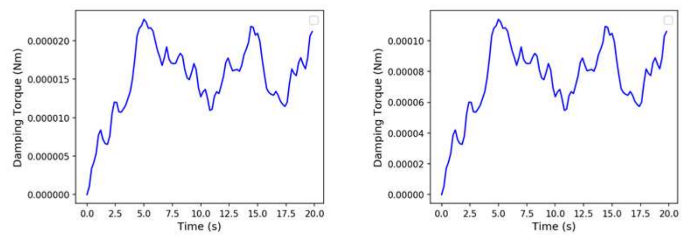

Figure 3: A comparison of the graph for damping torque against time when torque=1N **(left)** and torque=5N **(right)**.

The influence of the torque on the oscillation was not apparent before the magnitude of the torque is in its hundreds.

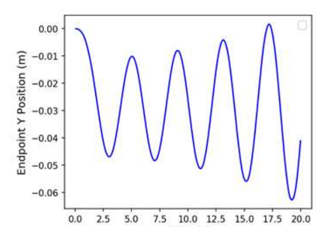

Figure 4: Plot of the Y position of the rod's free end against time when torque=300N

The torque acts similar to a driving force in this context. It was also noted that applying a left-handed torque also yields the same outcomes as applying a right-handed torque. The initially smooth evolution of internal stress over time also becomes jagged in this region.

Conclusion

Using PyElastica, one is able to shed light on the effects of forces and/or torques on a rod by analysing multiple variables throughout the simulation. Future work will involve applying forces and torques at different points on the rod, stretching, and incorporating more elements into the simulation (e.g. gravity, helical buckling and slender body theory) to further increase its relevance to real-world applications and related experiments.