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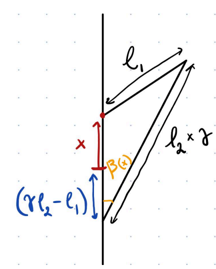
MPS 5 Writeup

Functional Requirements

	Description	Value	Range	Justification
Energy	Total energy stored	0.75 J	+5 J -0 J	Based on the potential energy of a 10g pencil at 1.5m (.225J) with 3x safety factor. The upper limit is to limit the destructive power of the pencil.
Stress	Maximum stress felt in the device	28 MPa	+0 MPa	28 MPa is about the lower bound UTS for ABS per McMaster. As we do not want our flexures to yield, this is the maximum allowable stress.
Force	Force for actuation	7 lbs	± 2 lbs	A person can apply within this range of force without needless difficulty.
Repeatability	Target size	0 mm	±200 mm	The range is given in the project requirements.

Modeling



To find the energy stored in the flexures, we first find the PRBM flexure angle as a function of x, the launch axis, using the law of sines to solve for $\boldsymbol{\beta}(x)$

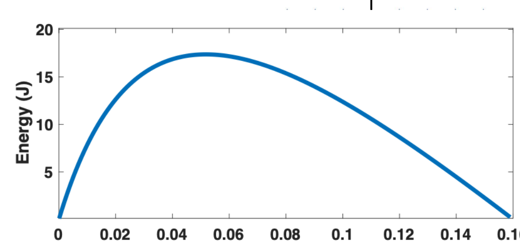
$$\frac{sin(\boldsymbol{\beta}(x))}{l1} = \frac{sin(\boldsymbol{\alpha}(x)+\boldsymbol{\beta}(x))}{\gamma l2} = \frac{sin(\boldsymbol{\alpha}(x))}{\gamma l2 - l1 + x}$$

To find the rotational stiffness we use the pinned cantilever equation

$$\mathbf{K}_{\mathbf{rotational}} = 2K_{\Theta}\frac{\gamma EI}{l2}$$

This gives us the energy.

$$E(x) = \frac{K\boldsymbol{\beta}(x)^2}{2}$$



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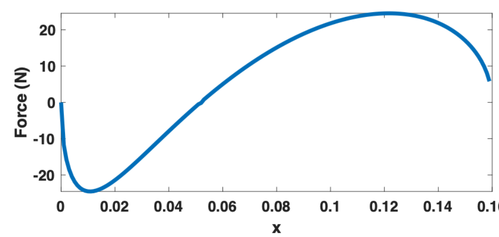
Next, we find the force required to set the mechanism and that launches the pencil. The tangential force is found using Hooke's law.

$$F(x) = K\boldsymbol{\beta}(x)$$



We find the force in x from the reaction force on the link

$$F_x(x) = F(x)cos(\phi(x))$$

Where $\phi(x)$ is the angle of the rigid link w.r.t to the x axis

$$\phi(x) = \boldsymbol{\alpha}(x) + \boldsymbol{\beta}(x)$$

The maximum stress occurs at the end of the flexures and it is given by:

$$S_{max} = Mc/2I$$

We calculated the force at each node and then the maximum stress at each flexure.

$$F = K\boldsymbol{\Theta}/\gamma l cos\Theta$$

We made sure that all stress was lower than the maximum stress for ABS (2.9 x 10^7 Pa).

Experimental Verification of Performance

To verify the performance of our device, we attempted to launch pencils with it and visually assess the height and distance achieved. Unfortunately, the projectiles did not make it as far as we hoped they would. We believe this is because our device stored only 0.3 J of energy, not enough to overcome the impact of friction.

We double layered two of our flexure elements and found that the pencil went further, though still not far enough. Had we had more time to source sufficiently long bolts, we would have tried adding a third layer—the force needed to actuate the double-layered was still small enough that the third would not make the device too difficult to use.

We also recognize that we may not have tested our device to its full potential. Having believed that the intention of the assignment was to have the energy of the pencil come from the device's stored energy, we actuated it by moving the launcher to just past its unstable equilibrium. During lecture, however, we saw other groups provide a greater impulse to the pencil, and Professor Culpepper seemed surprised at how gentle we were with our launcher. We are not sure how great of an improvement a greater actuation force would have on our device, but believe it might be notable.

Reflections

From this MPS, the greatest thing we took away is the importance of recognizing all the parts of the system that use up energy. Friction consumed a lot more energy than we expected. Further, in talking with Dan afterwards, he noted that the thickness of our linkages may have also added unnecessary mass, hindering the acceleration of the pencil; we had not considered that when modeling.