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MPS 3: PRBM - Egg Gripper

Functional Requirements: MPS 3 Functional Requirements

	Description	Value	Range	Justification
Egg Force	Total force on the egg from all points of contact	15N	±5N	7N is required for the egg not to slip, while more than 31N will break the egg. This range includes a 1.5x safety factor
ROM of moving component	Range of motion of the gripper arms	42 mm	± 7 mm	4.45cm diameter largest egg. This allows enough space for the egg to be picked up.
Max Stress on Compliant Parts	The maximum stress on the compliant piece due to the clamping force	28 MPa	max	28MPa is about the lower bound UTS for ABS per McMaster
Stiffness	Stiffness of the beam contacting the egg	10,000 N/m	±3,333 N/m	Used min and max force exerted on the egg for a displacement of 1/16" (this is the amount that foam is able to compress)
Range of Input Forces	range of allowable input forces to actuate the device	10lbf	±2lbf	"Am I gripping it?" haptics. reasonable gripping strength is about 5lbf
dynamic holding	dynamic holding	0.8g force	±0.2g force	added g forces from moving the egg+gripper around.

PRBM on flexures

We used Pseudo-Rigid-Body Models (PRBM) of fixed guided flexures to design our compliant mechanism. A fixed guided flexure has a rigid body equivalent of 3 linkages connected by torsional springs, with one linkage grounded. The stiffness K is given by:

$$K = \frac{2\gamma K_{\theta} EI}{l}$$

We found appropriate values for $\gamma = 0.85$ and $K_{\theta} = 2.65$

The force required for a given deflection of the beam (from our functional requirements) is given by:

$$F = \frac{4K\theta}{\gamma l \cos\theta}$$

where θ depends on the deflection δ. Given our design requirements, $\delta = 1cm$. Using this, we could directly relate F with l, since θ is a function of l and δ.

We also have that the maximum stress occurs at the end of the flexures and it is given by:

$$S_{max} = \frac{Fac}{2I}$$

where $a = \gamma l$ and c is the distance from the neutral axis to the outer fibers.
We designed our mechanism so we could minimize the stress, while maintaining force and stiffness in the intervals of our FRs.

Padding Beams

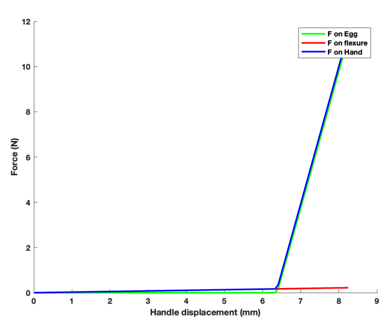
We calculated the stiffness of the padding beams which were used to hold the egg based on an empirically determined maximum egg load of 31N. Using the equation for a centrally point loaded clamped beam:

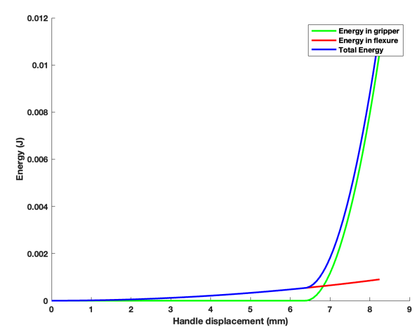
$$F = \frac{192EI}{L^3}\delta$$

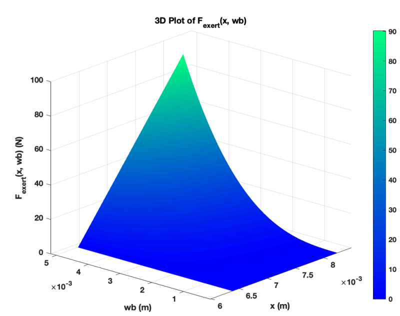
We designed our padding beams such that they would displace at most $1mm$. This led to a predicted force on the egg of 10.6N per padding beam. Based on the relationship between force and stiffness, we predicted a stiffness of 5.7 kN/m.

The gripper stiffness is the combination of two padding beams in parallel at 30 degrees, which is in series with the bottom pad. $K_{gripper} = \frac{1}{\frac{1}{K_{pad}} + \frac{1}{2K_{pad,30deg}}}$

Total Energy, Force, Stiffness, and Sensitivity







Using the PRBM model for the flexures, and a static model for the grippers, we can find functions for the force and energy in the gripper, the flexure, and in total by combining them with their respective ranges.
Since the stiffness of the gripper scales with the cube of the padding beam width (wb), we chose a lower value to ensure fabrication imprecisions would not significantly alter the stiffness.
The force analysis reveals that the padding beams are the main contributors to the force exerted on the egg. The range of forces, particularly when the device is fully closed, lie within the desired range (15 +/- 5 N).

FEA Verification

After we obtained all of the required dimensions from our modeling, we did an FEA on the compliant piece to confirm that it would not break. A screenshot is attached to the right.