ME23N - Soft Robotics for Humanity
Stanford University
Mechanical Engineering
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Lab 5: Elastomeric Soft Gripper

I. Overview

In this lab we will investigate elastomeric materials, like silicone or rubber, and how these materials can be used in soft robotic actuators. We will mold a soft, two-part elastomer into a four-fingered pneumatic gripper which we can then use for adaptable soft grasping.

Elastomers (a portmanteau of *elastic polymer*) are defined by their low *elastic or young's moduli* (which allows them to be stretched with low input force) and the high *failure strain* (which determines how far they can be stretched before tearing). This means that, unlike materials we have used in the previous labs, elastomers can expand and stretch in all directions. Elastomers are made of long polymer chains that are linked together in such a way that they can easily be stretched out.

Many soft robot designs, for a wide range of applications, are made of elastomers because they are easy to produce in a wide range of shapes, and their elasticity (like in rubber bands) gives a returning force when they are stretched. The shape of the elastomer will determine what happens when you apply a force or pressure and many designs add in stiffer materials or inextensible materials to direct the stretching. Here we use inextensible fabric to get the gripper fingers to bend.

In this lab we will be using a technique called **molding** to create our elastomer shapes. Molding involves making a *negative* of the shape that you want to produce (often using 3D printing or machining) and then pouring special, two-part elastomers into the mold, which start liquid and solidify over time, yielding the *positive* of the shape you want. Molding can be useful for shaping materials that are difficult to machine, and for creating interesting geometries.

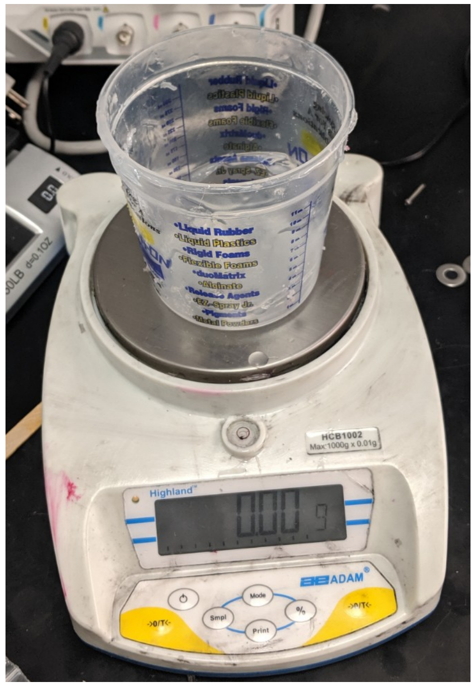
II. Materials and Equipment

- EcoFlex 00-30 (Part A and Part B)
- Air Tube (4.5/32”)
- Silpoxy Silicone Adhesive
- Push-to-Connect Connectors and Adaptors
- Silnylon (Silicone Impregnated Ripstop Nylon)
- Gripper Mold
- Paper Plate(s)
- Mixing Cup and Stick
- String

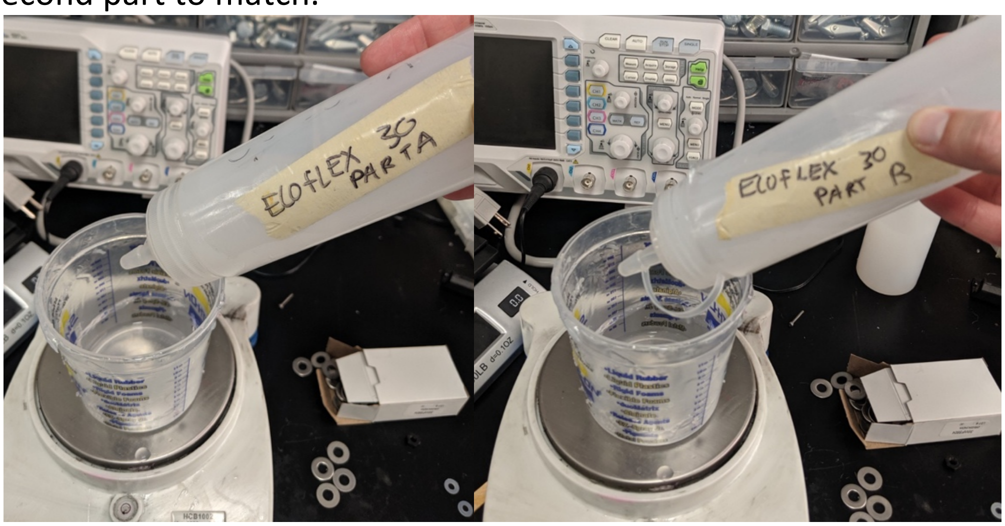
- Scissors
- Tweezers
- Weights
- Silver Paint Pens
- Positive Pressure Hand Pump

III. Steps

1. Start by measuring and mixing the silicone. To do this start by placing the measuring cup on the scale and zero the scale.



2. Measure out equal parts of EcoFlex 00-30 Part A and EcoFlex 00-30 Part B by weight, **using about 100 g total (i.e. 50 g of each part)**. First, measure out one part to approximately half the desired weight and then measure the second part to match.

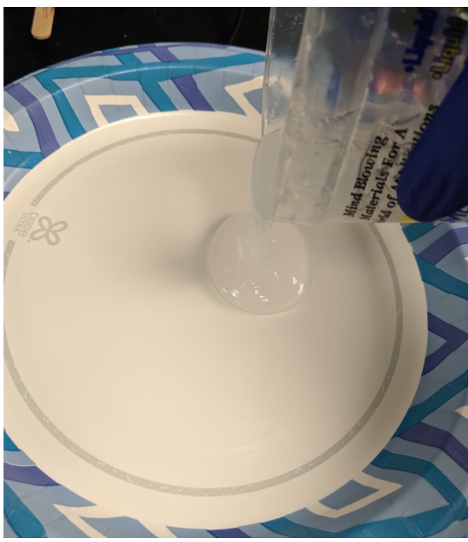


3. Mix the two parts together well using the mixing stick.

4. Put the gripper mold onto a paper plate. Pour the silicone mixture into the gripper mold, filling it all the way to the top. Keep the mold level.

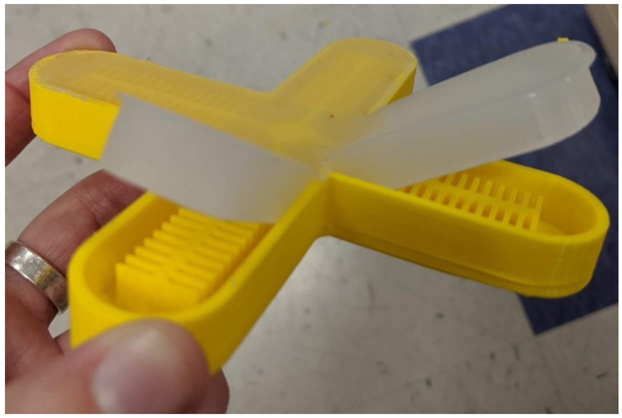
 

5. Pour the remaining silicone that you mixed onto a second paper plate. This will create a sheet of silicone.

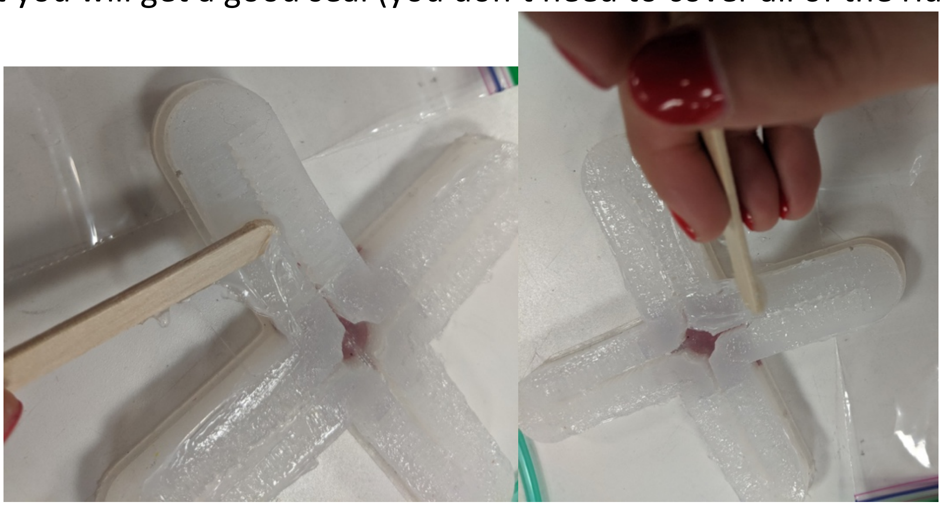
 

6. Place the two plates on level surfaces to cure for at least 4 hours.
   (END HERE ON FIRST DAY)

7. *Carefully* remove the cured silicone from the mold **(BUT NOT FROM THE PLATE)**.

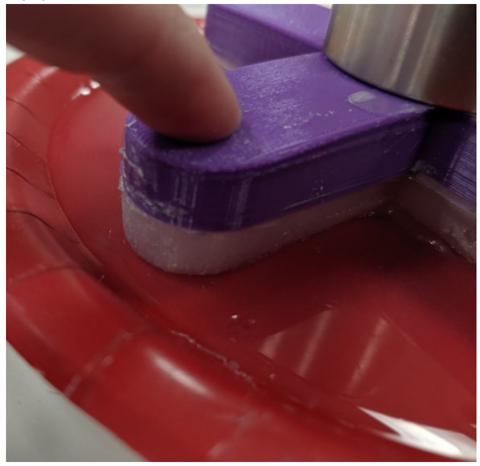


8. Use Silpoxy silicone adhesive to connect the gripper silicone to the silicone sheet. Spread a good layer of Silpoxy on the **open** side of the gripper silicone. Make sure to get a lot of Silpoxy all the way around the edge so that you will get a good seal (you don't need to cover all of the ridges).



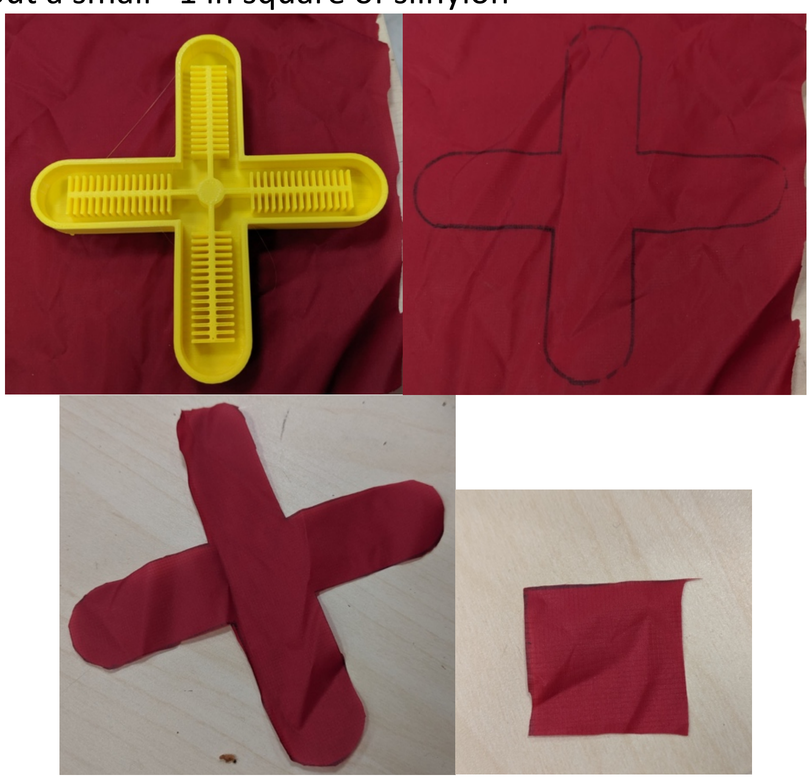
9. Press the gripper silicone onto the silicone sheet. Make sure all of the edges are pressed down. You can use a weight or the mold to help the pieces together while they glue. You should see some Silpoxy get squeezed out.

10. Make sure the pieces are firmly pressed together (Silpoxy might squeeze out the edges of the gripper, this is ok) and let sit for at least 30 minutes.



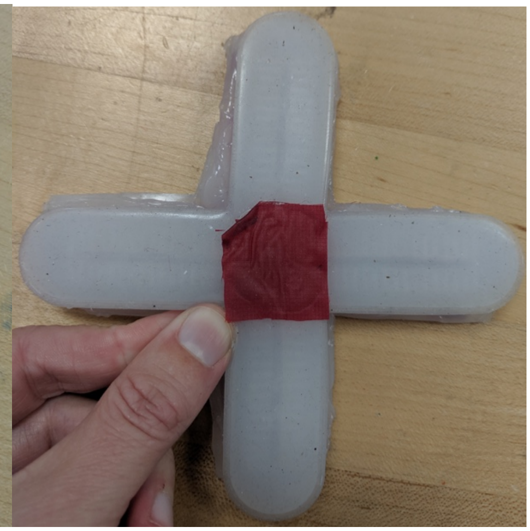
11. While you are waiting, test out the silicone stiffness properties using the steps in **Part IV**

12. Trace the gripper mold onto the silnylon. Cut out the cross-shaped pattern. **Also** cut out a small ~1 in square of silnylon

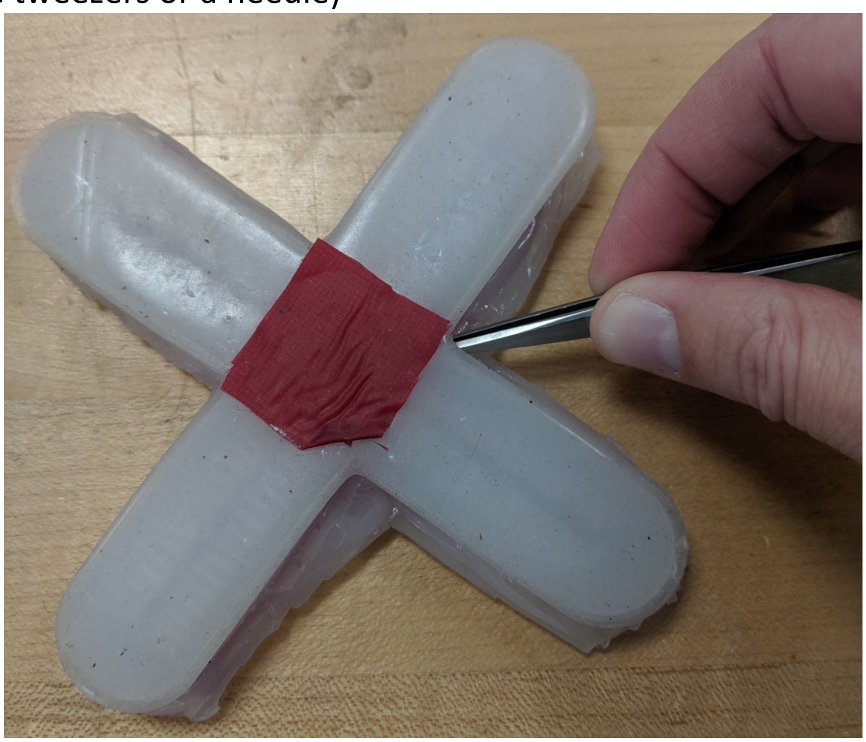


13. Remove the full silicone gripper from the plate. Carefully trim the silicone sheet so it matches the gripper silicone piece you glued it to.

14. Use Silpoxy to attach the silnylon cross to the bottom of the silicone sheet. Spead a thin layer of Silpoxy and press the silnylon on. Do the same with the silnylon square on the other side of the gripper in the center. Let sit for at least 5 minutes.

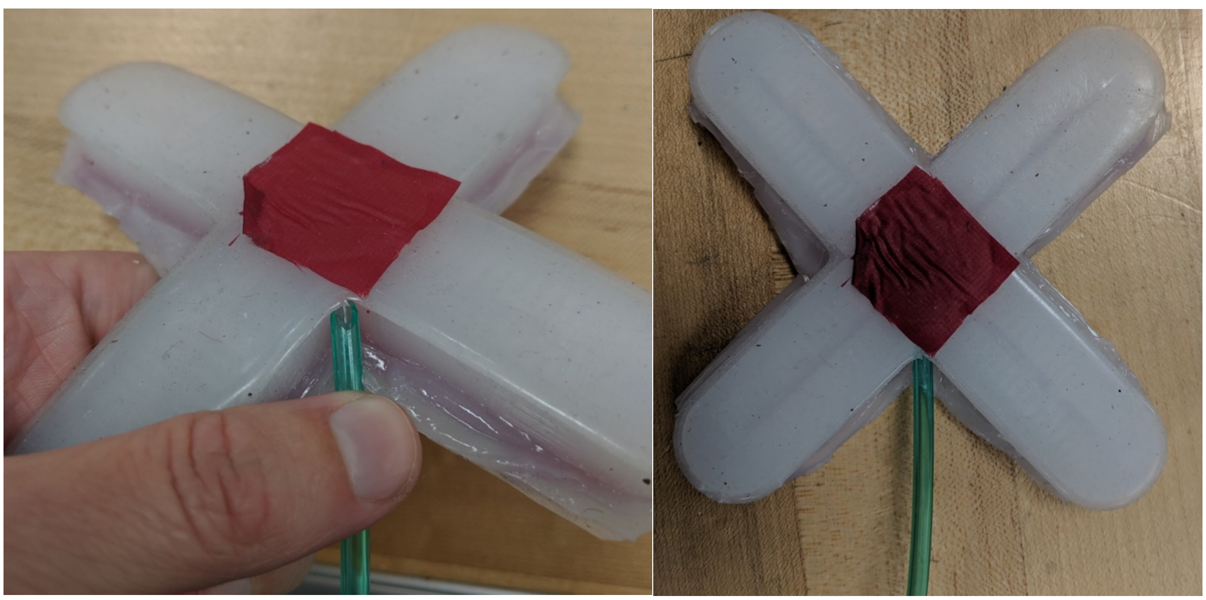



15. Poke a small hole in the side of the gripper between two of the “fingers” (use the tweezers or a needle)

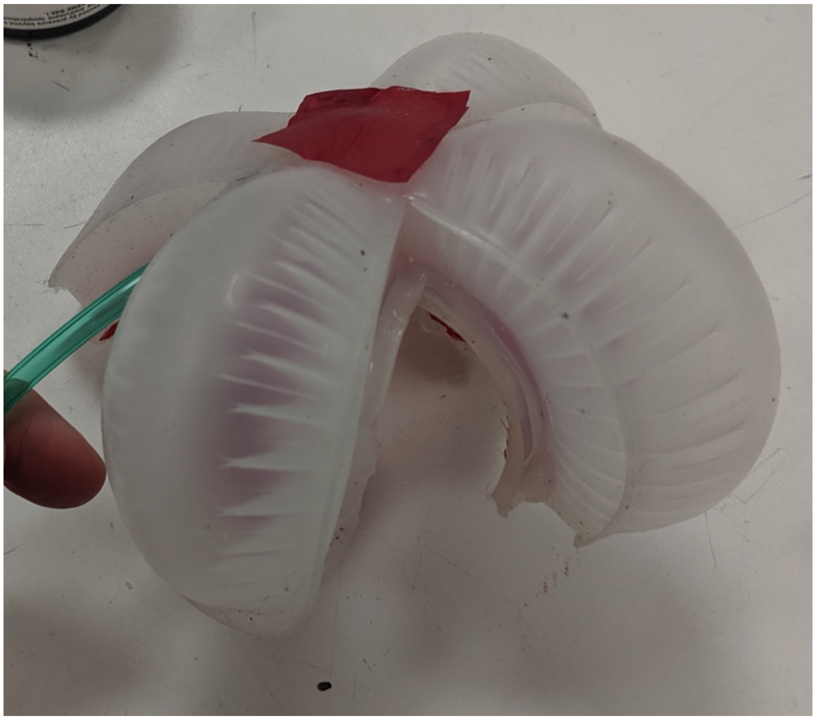


16. Cut a point onto the tubing so that it is easier to push into the hole in the silicone.

17. Push the tube in. This may be a little difficult, but that means the seal around the tube will be better.



18. Attach the gripper tube to the hand pump and inflate it. Try to pick up some objects.



IV. Material Testing

1. In this section, we will investigate the stiffness properties of the silicone used in this lab. Cut a test piece of silicone, about 3 inches long and ½ to 3/4 inches wide from the test silicone sheet (see TA's for where this sheet is)

2. Take a piece of string and tie one end *securely* around the end of the test piece.

3. Tie the other end of the string into a loop with a slipknot, to attach to the weights (see the TA's if you need help with the knot).

4. Mark two points on the silicone with sharpie and measure their initial distance apart. You will use these points to tell how much the silicone stretches.

5. Attach a weight to the string slipknot (attach around the "neck" of the weight) and pull on the other end of the silicone test strip to lift the weight.

6. Measure and record the new distance between the marks (the stretch) and the weight you attached.

7. Repeat this for 3-5 different weights

V. Questions

1. Test the material properties of a silicone sample (see Section IV). Write down the size of your sample (length, width, thickness), the weights tested, and the change in length between your measurement points. Sketch out a plot of the points you tested. Does the stretch seem linear? What is the stiffness ($k = \frac{F}{\Delta L}$), i.e. the slope of the line? What was the maximum stretch you found?

2. Calculate the stress and the strain for each of your tested points. To do this you'll need to know the cross-sectional area of your sample and the amount of force that the weight creates. Remember: stress is calculated from $\sigma = F/A$ and strain is calculated from $\epsilon = (L - L_o)/L_o$, where $L_o$is the starting length and L is the final length. Find the Young's modulus of the material (slope of the stress-strain line). Compare the results you found to other groups'.

3. Describe how the soft elastomeric gripper works. What is the pressure doing? What is the function of the fabric? What do the ridges in the mold (creating all the different chambers) do?

4. How well does the gripper work for picking up objects? How much weight can it lift? Can it lift oddly shaped objects? What do you think is the best application for a gripper like this?

5. What are other potential uses for elastomers in soft robotics? Imagine some other use cases, either using air power or using other actuation types.

6. Any other thoughts?