ME23N - Soft Robotics for Humanity
Stanford University
Mechanical Engineering
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Lab 2: Particle Jamming Gripper

(adapted from: www.instructables.com/id/DIY-Universal-Robot-Gripper/)

I. Overview

In this lab we will be making a gripper that uses adaptability and stiffness change to grip a wide range of objects. Many traditional and soft robotic grippers use bioinspired forms that act like fingers or tentacles to grasp objects. These grippers are dependent on identifying good contact points on the object. Imagine trying to pick up an object between two fingers, using only your fingertips. The gripper we will be making in this lab instead relies on its deformability (low stiffness) to passively adapt to the shape of the object, at which point it stiffens to allow the gripper to exert higher forces. These grippers can grip using surface features (B) or by surrounding an object (C).

The mechanism of stiffness change used in the gripper is called particle or granular jamming. A collection of small particles, like sand or coffee grounds, inside a deformable membrane can move freely past each other normally. When the air inside the membrane is evacuated, the small particles lock together and become “jammed”. This increases the apparent stiffness of the gripper since the particles no longer move freely past one another.

The stiffness that can be achieved is dependent on two factors: the normal force between the particles and the friction coefficient of the particles. The vacuum (negative) pressure generates the normal force and the particle material determines the friction. To get good jamming, you must be able to generate a significant vacuum pressure and you must use particles that easily catch on each other. Similar types of stiffness change through jamming can also be used with lines of material (called linear jamming) or thin sheets of material (called layer jamming).

II. Materials and Equipment

- Balloons
- Plastic Funnel
- Coffee Grounds
- Sand
- Tape
- Air Hose/Tubing
- Quilter Stuffing
- Zip Ties

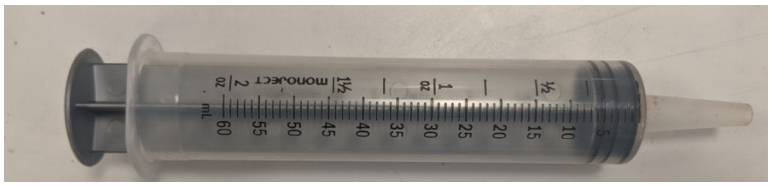
- Scissors
- Wire cutters
- Tweezers
- Hand pump
- Syringes

III. Steps

1. Fill the balloon with your particles (either coffee grounds or sand). To do this, attach the balloon to the end of a short tube or pipe and insert the funnel into the other end (you can also put the funnel straight into the balloon). You can make a tube from plastic sheet or acetate. Scoop about a tablespoon of material into the funnel and it will pour down into the balloon. After each scoop, remove the funnel and gently blow into the tube to partially inflate the balloon and allow all the particles to settle to the bottom.

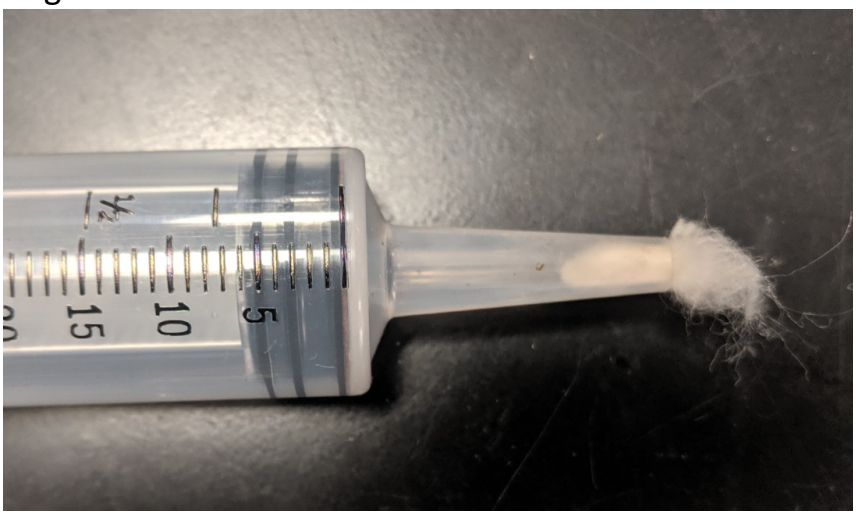
2. Repeat this step until the balloon is sufficiently filled, stopping occasionally to check the size of the balloon inside the funnel. When you fit the body of the balloon into the body of the funnel, the filled balloon should stick out of the funnel by about an inch. Take the balloon off the tube when you have enough particles.

3. If the “neck” of the funnel is too long, cut the end of the funnel off (using the wire clippers), leaving about a half inch of the neck of the funnel. Make sure there are no sharp spots that will tear holes in the balloon
4. From this point, you will attach the balloon to your vacuum source. How you attach it will depend on what type of syringe or hand pump you are using, so make sure you follow the instructions for the one you have.
5. If you are using the syringes with the tapered end (this is easier to get an air tight fit):



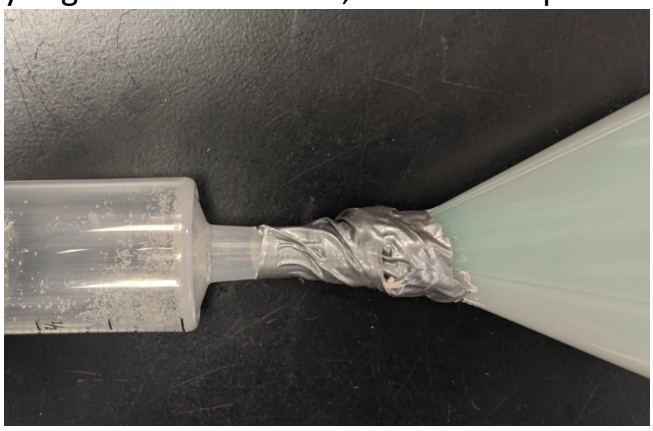
a) Pull the neck of the balloon through the funnel (try using the tweezers if you are having trouble) and wrap it around opening. Tape the balloon neck in place to keep the balloon secure in the funnel. Be careful not to spill the coffee grounds/sand.

b) Stuff some quilter stuffing into the syringe tip, leaving a good amount sticking out

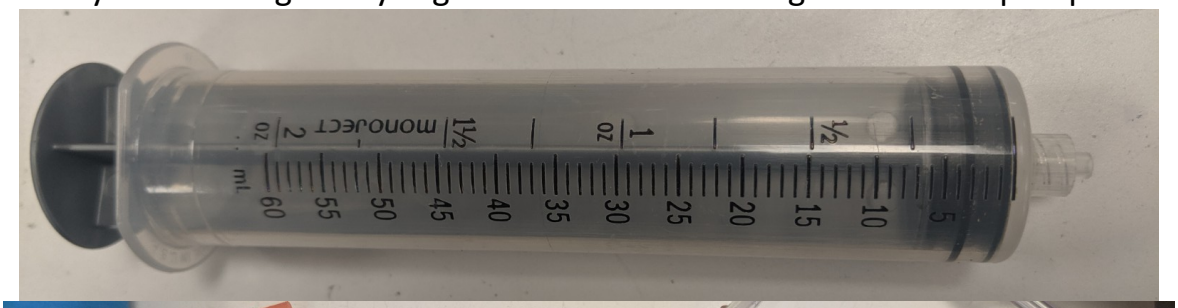


c) Push the syringe into the funnel neck, where the balloon was taped. **Make sure the plunger position in the syringe is slightly away from the end** (see picture).

d) Tape the syringe onto the funnel, to hold it in place

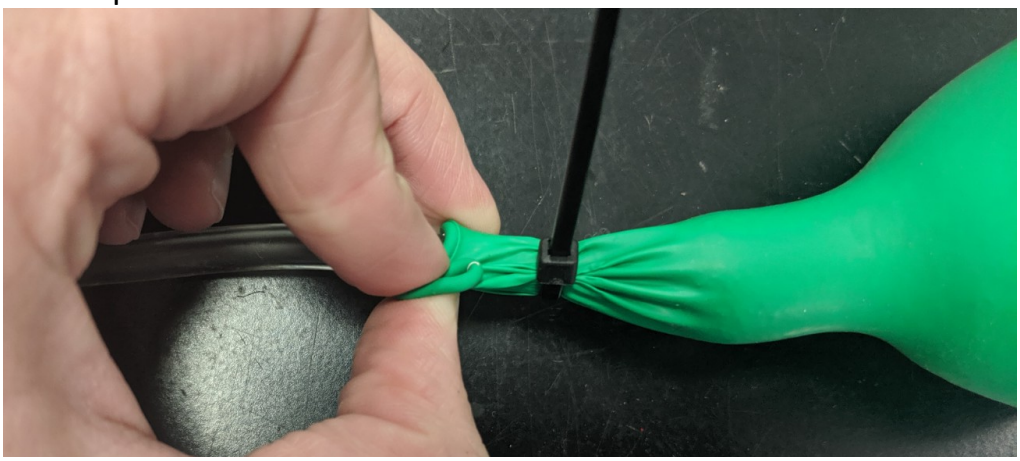


6. If you are using the syringes that attach to tubing or the hand pump:

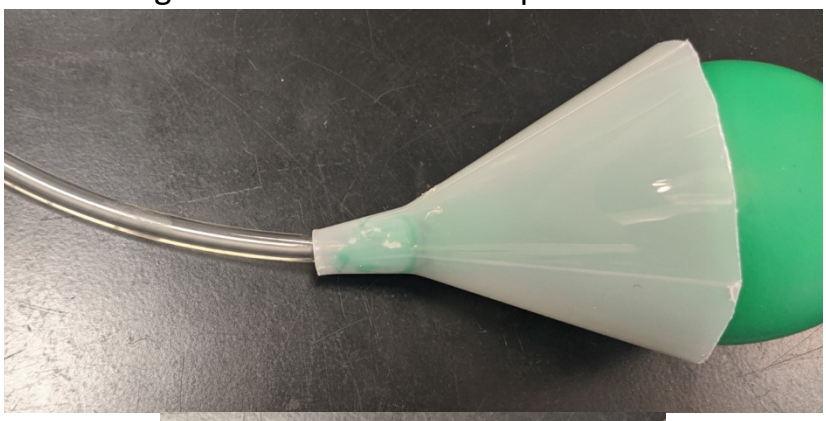


a) Get a piece of ¼” diameter tubing. Stuff (using tweezers) quilter stuffing into the tubing, leaving some amount outside.

b) Zip tie the tubing into the balloon. Get the zip tie tight! Clip the end of the zip tie.



c) Pull the tubing through the funnel, to pull the balloon into the funnel. Tape the tubing onto the funnel to keep it secured.



d) Attach the tubing to the syringe (or to the hand pump). If you're using the syringe, leave some air inside when you attach to the tube.

7. To use the gripper, inflate it slightly with positive pressure, either with the hand pump or by pushing the syringe plunger in (you will need to change the setting on the hand pump). Push the gripper over the object you want to grasp. Then deflate the gripper and pull vacuum to grasp (pull the syringe plunger out or set the hand pump to vacuum).
8. Pick up some objects! Experiment with different objects to see what makes an object easy to pick up with the universal gripper and what features make it difficult to pick up.
9. Try modifications on the gripper, using sand instead of coffee grounds or vice versa, using different amounts of fill, etc.

IV. Questions

1. Describe how the particle jamming gripper functions.
   a. How does jamming occur? What effect does the particle material have on jamming? Do you think jamming would work better with smooth particles or rough particles?

   b. How does the gripper apply forces on the object being grasped (friction force, normal force)?

   c. What properties of the membrane are important for the gripper to function (flexibility, elasticity, friction)?

2. Try to pick up at least 5 different objects (different as in varying in shape, size, weight, etc.). Record multiple grasps and the success of each grasp. For successful grasps, note how difficult (how much force) was required to pull the object out of the gripper. For non-uniform objects, note if some directions of grasping the object were more successful than others. Try grabbing the objects with the toy claw grippers as well. Make a table of your objects, grasp successes, and notes.

3. Describe the features shared by objects that were easy to grasp with the particle jamming gripper. Describe the features shared by objects that were difficult to grasp. How do these features relate back to the gripper function? Were there any objects that were easier to grab with the jamming gripper than the toy claw, and vice versa?

4. Any other thought?