

Fingers

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1 Introduction

We decided to add actuators to the gripper to improve his performance. The idea was to combine the jamming with hydrostat actuators with a geometry made to have a flexible internal volume that allows the structure to bend like a finger, helping the gripper to take objects of differing shapes and sizes.

We decided to start with the simplest design possible with the actuators attached to the outside of the membrane as represented on the right. In that way we don't have to change the actual design and the test phase will be fast. The actuators have the only task of better distributing the unjammed particles around the object, while membrane must still maintain a strong hold. The material of the actuators must be soft to avoid damages on the objects. There are many projects about actuators in soft robotics. One way to realize them found in literature [1] is using a mold 3D printed to create fingers in silicone rubber. The shape of the mold was based on this one, with some changes to easily connect it to our gripper.

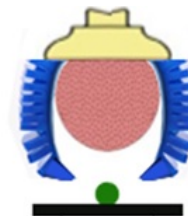
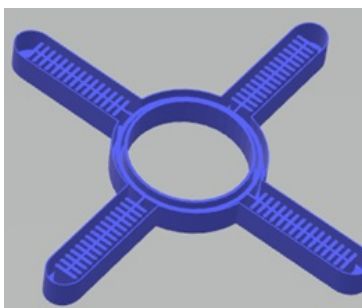


Figure 1: The first conceptual design



(a) Picture extracted from the tutorial



(b) First mold designed

Figure 2: Caption for this figure with two images

For the first test it was chosen a length of the actuators of 4 inches and a

width of 1 inch. As shown on the pictures there are many chambers in the actuator and air pumped in the 4 actuators will bend them. The mold was printed in PLA with the 3D printer model **Prusa I3 MK2S** and for the actuators the material chosen was **Ecoflex 00-30 [1]**, bought on www.reynoldsam.com. This material is a silicone rubber extraordinarily soft, strong and durable.

As described on Instructables [?](#), the separate fingers were closed by a bigger layer of silicon rubber.



Figure 3: picture from the tutorial to close ecoflex

2 Results with the first geometry

The results were not satisfactory. The mold was not right positioned and the silicon was not evenly distributed.

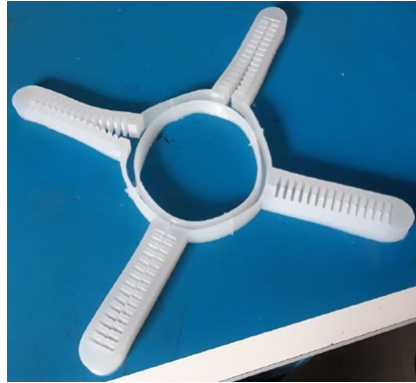
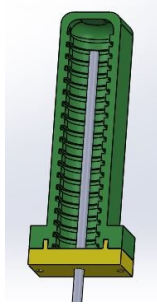


Figure 4: First result from the mold

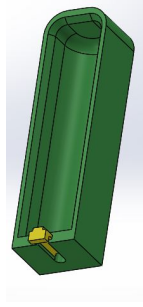
The casting was divided in four parts to test every finger separately, and to realize four different tests. To bend in a good way, the actuator's sides need to have two different stiffness, so that one side will stretch and the other just bend. In that way the movement of the actuator was not good controlled and the grip not strong enough. It was necessary to tighten up one side of the finger.

3 Steps to realize the soft robotic finger

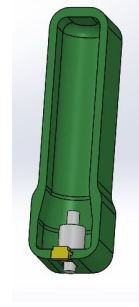
We tried to realize a finger realized by a high repeatable process. To do that we are using three different molds.



(a) First step mold



(b) Second step mold



(c) Third step mold

Figure 5: Molds utilized

It is based on 6 steps:

1. Filling of the first mold with EcoFlex 0030
2. Add a layer of Smooth-Sil 950
3. Ribbon wrapping
4. Cover all with SortaClear 40 using the second mold
5. Realize the cover to joint the finger with the connector with the third mold
6. Use the silicone glue to attach the connector inside the cover realized

Every time a mold is filled by a silicon rubber we used the vacuum chamber at 1 bar *at about* 5 minutes, to reduce the number of bubbles, and the pressure chamber at 2 bar for all the time of curing to reduce the dimension of the bubbles remained in the mix .



Figure 6: Vacuum chamber and pressure chamber

3.1 EcoFlex 0030

To realize the first step we used the EcoFlex 0030 in the first mold. The internal cavity is realized by a cylindrical aluminum pin of 4mm of diameter, that will be extracted after the third step. For this step it is necessary approximately 20 grams of silicon rubber. To control as well as possible the quantity the mold has a line defining the boundary to reach.

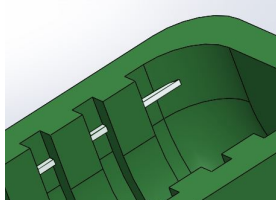


Figure 7: Line to define the boundary to reach with EcoFlex 0030

3.2 Smooth-Sil 950

To bend the finger with the high pressure it is necessary a stronger layer to allow the bending, preventing the elongation in one side. After few tests we decided to use this material. Without put out the solidified EcoFlex from the first mold it is filled the remaining space in the first mold with the Smooth-Sil 950, in that way is easily controlled the thickness of this layer.



Figure 8: Smooth-Sil 950 filling

3.3 Ribbon wrapping

To control the bending of the finger it is necessary to reduce the radial deformation. A possible way is by wrapping a ribbon all around the shape of the finger and depending on how the ribbon is wrapped it changes the way to bend. To make easy the wrapping it was added a guide for all the finger.



Figure 9: Wrapper finger

3.4 SortaClear40

The reasons of this step are to have a smooth geometry covering and preserving the ribbon and because the EcoFlex 0030 is too flexible and during the bending the high pressure causes the excessive swelling between one winding and the other.



Figure 10: Picture of the finger without and with the cover in SortaClear

3.5 SmoothSil 950 connector covering

To connect the finger to the manifold we are using a male quick connector. it is necessary a stable and durable connection between the finger and the manifold, because of that it was used the SmoothSil 950.

The connector is added at a later stage to add silicon glue between the connector and the SmoothSil 950 cover.



Figure 11: Male quick connector (<https://www.mcmaster.com/5012k45>)



Figure 12: Connector coverin SmoothSil 950

4 Implementation of the soft fingers to the double gripper on arm in water

Between the goal was to update and test the double gripper on arm in water.

- Replace all the hard component with soft components.
- Print hydraulic manifold in water resistant material.
- Refurbish water hydraulic system on arm to provide pressure and suction on different channels.

Among the components of the double gripper there were a central holding in PLA designed to have the toroidal shape and a strong cup to direct the movement of the balloon.

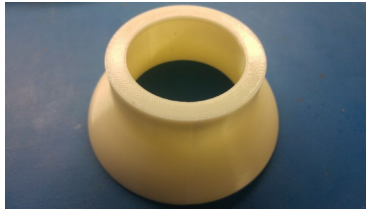


Figure 13: Cup



Figure 14: Central Holding

We chose to replace the central holding with a flexible silicone rubber tube of 5mm of diameter, the balloon will be connected on that tube by a cable tie. Therefore during the jamming also the center of the balloon is flexible and it cannot damage the object that it is grabbing.

The cup was replaced by 3 soft hydraulic fingers. To connect the 3 fingers we designed a new manifold with a second chamber to control the pressure inside the fingers separately from the balloon.

The manifold in the picture was printed by the 3D printer Form Lab 2 in clear resin. This is a water resistant material as requested. The fingers are easily connected to the manifold by plastic quick-disconnect tube.



Figure 15: New central holding



Figure 16: New manifold

References

Air-Powered Soft Robot Gripper <https://www.instructables.com/id/Air-Powered-Soft-Robotic-Gripper/>



Figure 17: The quick disconnect tube (<https://www.mcmaster.com/5012K29>)

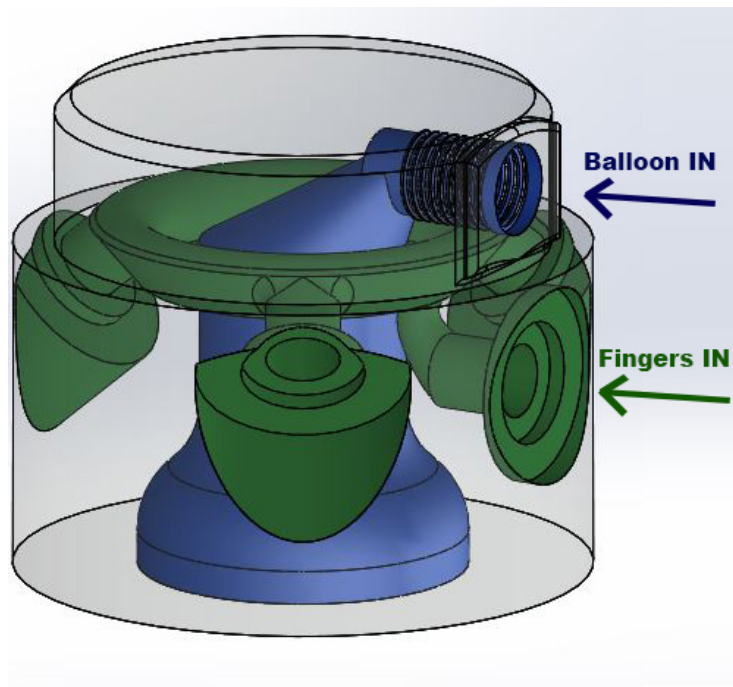


Figure 18: Manifold flow scheme