

Appendix B How to Make Pneumatic Air Muscles

B.1 What are Pneumatic Air Muscles?

Pneumatic muscles are one type of actuator that can be used to actuate a continuum surface. Although making pneumatic muscles may seem like a simple task, creating a long-lasting, durable muscle is not as easy as it may seem. We have outlined the steps to creating, what we deem to be, a reliable, lightweight, and effective pneumatic muscle.

Over the course of this research, we refined our procedures for muscle fabrication. From the photos, one will see how we have replaced the brass components with plastic. This greatly minimized the weight of the muscle, thereby increasing the degree to which the muscles induce curvature when attached to a surface.

B.2 Supplies

The first step to creating a pneumatic muscle is obtaining the correct supplies. Below is a list of the supplies that we prefer.

zip ties

Vendor: Lowes

High-Temperature Silicone Rubber Tubing

1/4 ID, 3/8 OD, 1/16 Wall

Vendor: mcmaster.com #5236K13

Expandable Mesh Sleeving

1/4 ID, 1/8 to 7/16 Bundle Diameter

Vendor: mcmaster.com #9284K324

Reducing Couplings, Tube to Tube

Nylong Reducing Cplg for 1/4" X 3/8" Tube OD

Vendor: mcmaster.com #5779K355

Durable Nylon Single-Barbed Tube Fitting Plug

1/4 Tube ID

Vendor: mcmaster.com #2974K781

Important Notes:

- The outer diameter (OD) of the rubber tubing should fall between the bundle diameters of the mesh sleeving.
- The inner diameter (ID) of the reducing coupling connector should be the same size as the outer diameter of the rubber tubing.
- The OD of the tube fitting plug should be the same size as the ID of the rubber tubing.

B.3 Cutting the Tubing

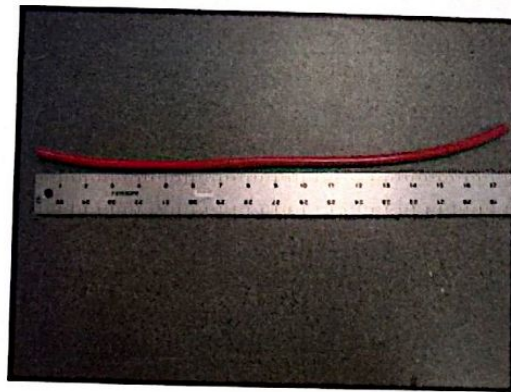


Figure 49: Cutting the Tubing

Supplies and tools needed:

- rubber tubing
- scissors
- ruler

Cut the rubber tubing the length that will result in the desired overall muscle length. At this step, it is important to know whether or not you have a maximum size that the overall muscle can be. This

is important to note because when the barb connector and tube plug are connected to the rubber tubing, the length of the overall muscle increases. If your muscle can be no longer than 10, you will want to cut the tubing to 9 3/4. If you do not have a length restriction and want to pressurize 10" of tubing, then cut the tubing to 10; just know that your overall muscle length will be approximately 10 1/4".

B.4 Securing One End of the Mesh

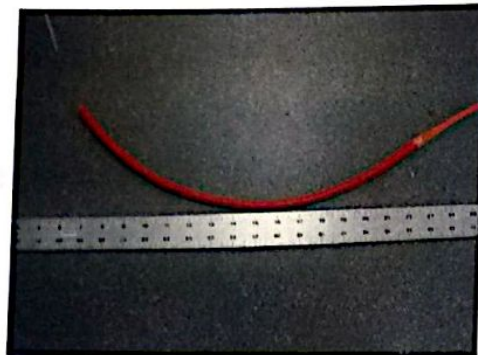


Figure 50: Applying the Mesh

Supplies and tools needed:

- mesh sleeving
- tube fitting plug
- zip tie
- scissors
- lighter

Before cutting the mesh, it is advised that you go ahead and place the tube fitting plug into one end of the rubber tubing and secure the mesh at that end of the tube. Be sure to push the tube fitting plug all the way into the tube.

Once the plug is in place, feed the mesh along the length of the tube – feed the side of the tube without the plug into the open end of the mesh first. Once the open-end of the mesh has reached



Figure 51: Securing the End

and is even with the end of the plug, stop feeding the mesh. Note: make sure to burn the open end of the mesh with a lighter before feeding the mesh; this helps to prevent fraying.

With the open end of the mesh still even with the end of the plug, retrieve a zip tie. Thread the zip tie through the mesh, around the circumference of the tube, and secure it. It is best to place the zip tie so that it is in the middle of the portion of the plug that is in the tube.

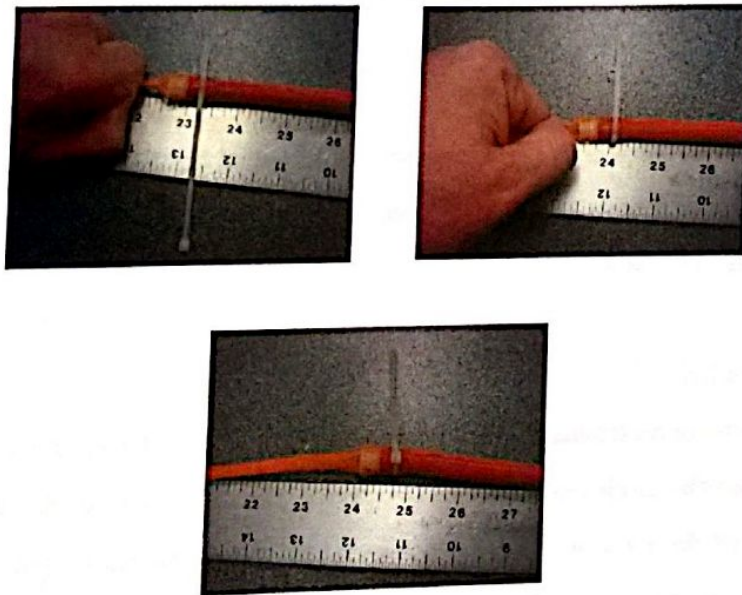


Figure 52: Securing the Mesh

B.5 Choosing the Type of Muscle

Supplies and tools needed:

- mesh sleeving
- barb connector
- zip tie
- scissors
- lighter

Depending on how you secure the mesh, you can create one of two different kinds of pneumatic muscles – an extensor or a contractor.

An extensor muscle requires that the mesh sleeving be bunched along the length of the tube so that when the rubber tubing expands, the mesh will be forced to extend. Therefore, the overall length of the muscle increases.

A contractor muscles requires that the mesh sleeving be pulled tightly along the length of the tube so that when the rubber tubing expands, the mesh will be forced to contract. Therefore, the overall length of the muscle decreases.

EXTENSOR MUSCLE

As mentioned, to create an extensor muscle, you must now bunch the mesh along the entire length of the muscle. Once the mesh has been bunched, grasp the uncut end of the mesh with the end of the tube. Then, cut the mesh at least an inch past the end of the tube. You can now release the mesh and burn the freshly cut mesh with the lighter.

The next step is to insert the open end of the rubber tubing into the reducing coupling. Now, you are in a position to secure the mesh around the middle of the reducing coupling. So, rebunch the mesh along the length of the tube; then, weave the zip tie through the mesh, around the reducing

coupling, and secure the zip tie. It is best to place the zip tie so that it is in the middle of the stem for the barb connect that is inside of the tube.

CONTRACTOR MUSCLE

As mentioned, to create a contractor muscle, you must now pull the mesh tightly along the entire length of the muscle. Once the mesh is tight, grasp the uncut end of the mesh with the end of the tube. Then, cut the mesh at least an inch past the end of the tube. You can now release the mesh and burn the freshly cut mesh with the lighter.

The next step is to insert the open end of the rubber tubing into the reducing coupling. Now, you are in a position to secure the mesh around the middle of the reducing coupling. So, pull the mesh tightly again along the length of the tube; then, weave the zip tie through the mesh, around the reducing coupling, and secure the zip tie. It is best to place the zip tie so that it is in the middle of the stem for the barb connect that is inside of the tube.

Note: Sometimes, it is necessary to add some electrical tape around the end of the tube that is being inserted into the reducing coupling to ensure a tight connection.

You now have a self-made pneumatic muscle.