

Design of Festo endcaps for muscle- like control in robotic Actuators

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What is an Actuator?

An actuator is a part of a machine that aids in controls or movement; adds strength

Actuators can be used to act like muscles in robots

- Muscles: force vs time contraction
- Robotic actuators: pressure vs time

Important for balance




What these actuators are made of:

Festo tube (12 in)

Adjustable clamps

End caps (1 ported 1 not ported)



Endcaps: how to make actuators act like muscles

Controlling the pressure over time in actuators to make them act like muscles → endcap design for proper leak rate

Accepted leak rate for single muscle contraction: 150 milliseconds



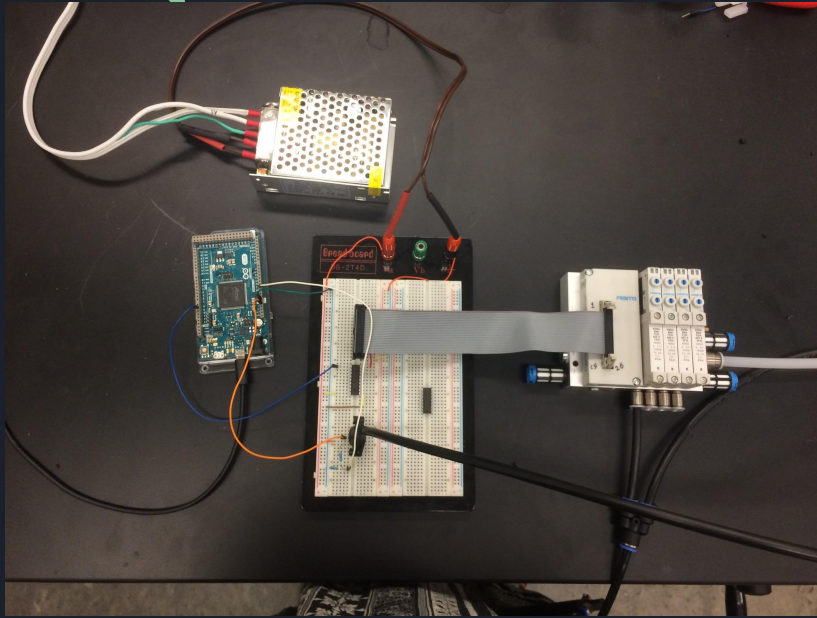
How end caps can be adjusted

3D print settings

- Wall thickness
- Roof and floor thickness
- Fill amount
- Fill pattern

Presence of, amount of, and size of hole

How the test was performed

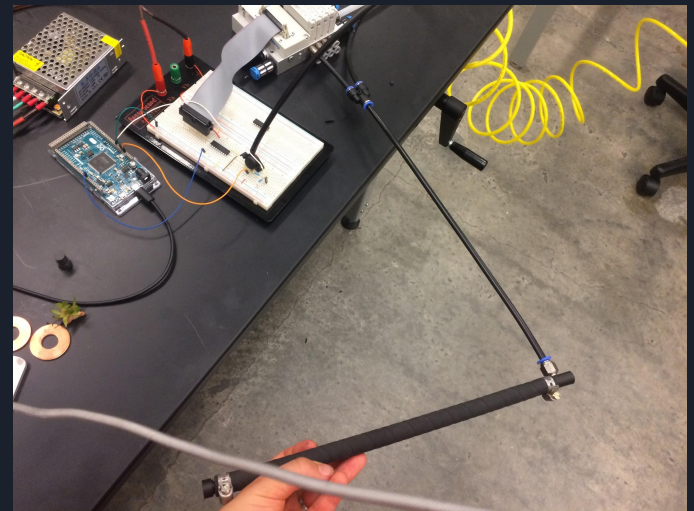
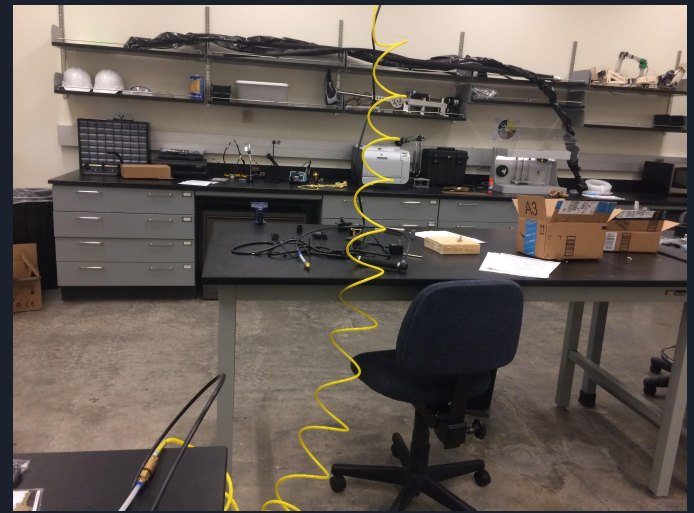
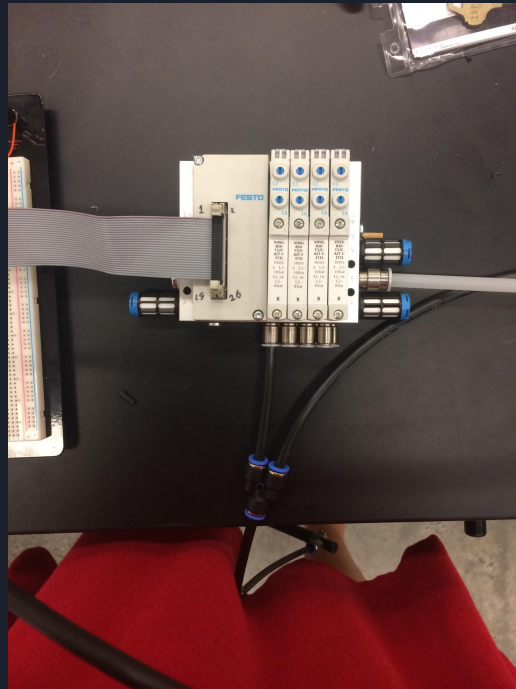
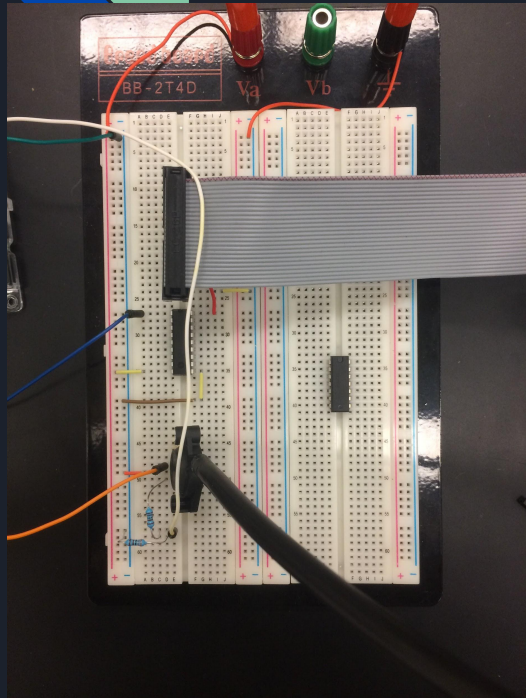


- Air supply attached to pressure valve
- Pressure valve attached to a pressure reader
- Pressure reader attached to a breadboard (electric circuit)
- Breadboard attached to an arduino board (programmable circuit board; microcontroller))
- Arduino attached to a computer

Code in the computer tells everything when to turn on and off and open

Pressure valve also attached to actuator and lets air in and out of it when told

Pictures



Code used

```
clear
clf
clc

a=arduino('COM3','Due');
c=0;
i=1;
tt=0;
time=zeros(1000,1);
Pressure=zeros(1000,1);
b=tic;
while c<5 %turn valve on and off 5 times
    bb=toc(b);
    Pressure(i)=readVoltage(a,'A0');%read pressure in volts
    time(i)=bb+tt;
    i=i+1;
    if bb<2.5
        writeDigitalPin(a,'D9',1)
    elseif 2.5<bb && bb<=5.5
        writeDigitalPin(a,'D9',0);
    elseif bb>5.5
        c=c+1;
        tt=toc(b)+tt;
        b=tic;
    end
end
pressure=((Pressure(:,:)/0.6554)-0.16)*(1000/6.4);
plot(time,pressure)
filename=input('input file name');
save((filename),'pressure','time')
```

This code opens and closes the pressure valve for each test 5 times.

The pressure is let in for 2.5 seconds, and left to rest for 3 seconds.

The arduino reads the pressure (in volts) off a pin connected to the pressure valve and stores it in the computer under the pressure matrix.

Time matrix is built as time passes

Code used cont.

```
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clf
clc

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```

The pressure matrix is converted from volts to kPA.

Pressure vs. Time matrices were plotted

The matrices were saved and stored on computer

Solidworks

Ported end cap

Solid end cap

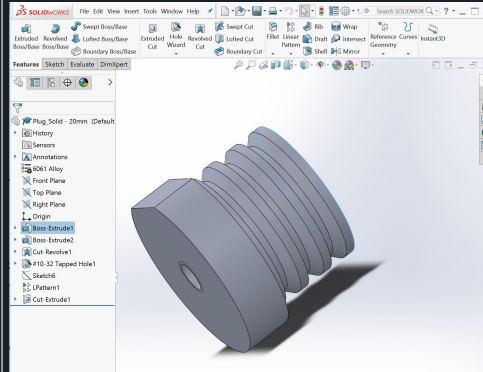
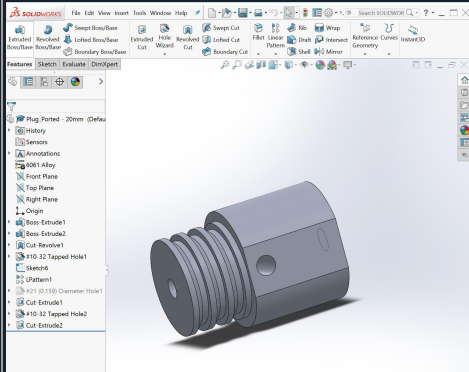
Adjusted radius of each

endcap

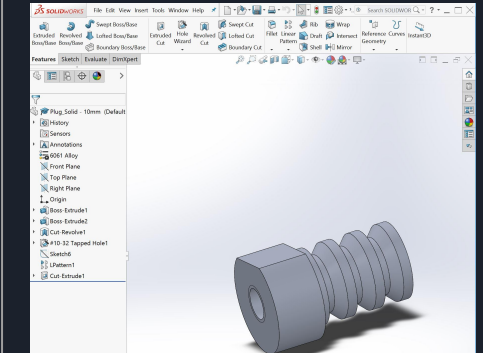
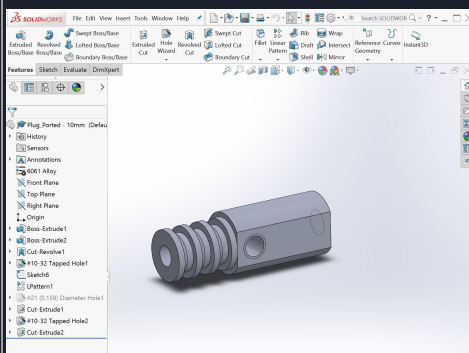
Adjusted hole sizes and

lengths

Original
file (20
mm
diameter)



New file
(10 mm
diameter)



Assembly



The hole had to be tapped for the pressure valve air screw to fit in it on the ported end piece

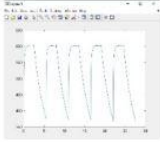
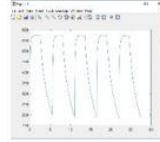
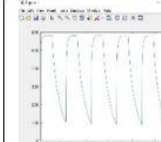
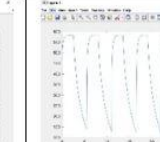
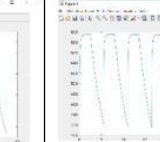
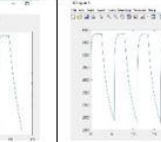
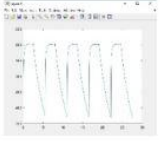
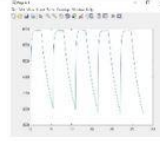
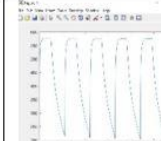
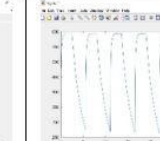
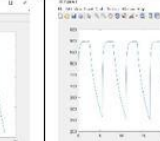
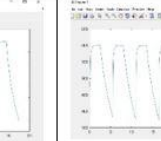
Testing different hole sizes

Then put end caps inside Festo tube (12in long) and clamped the end caps on as tight as possible

Attach to pressure valve

Ready to test!

Print and test 1

	Original	Hexagon fill	Triangular fill	Lower wall thickness	Lower roof and floor thickness	Lower fill
Type	Rectangular	Hexagon	tri	X	X	X
Fill	100	X	X	X	X	50
Roof and floor wall	4	X	X	X	3	X
	3	X	X	2	X	X
Trial 1 and lowest pressure	 375	 200	 100	 125	 420	 225
Trial 2 and lowest pressure	 375	 350	 200	 275	 250	 375

Only changed 3D printing settings: fill pattern, wall thickness, roof and floor thickness, fill amount

Changed only one setting with each test

None got close to a relaxed pressure state

Print and test 2

A hole (or holes) were added to the end cap that would allow for a significantly greater release in pressure (using original 3D printing settings)

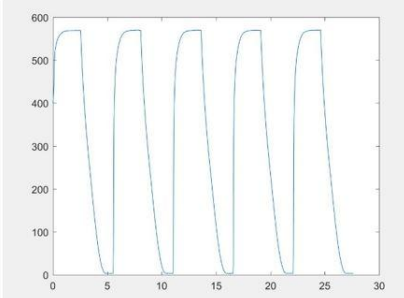
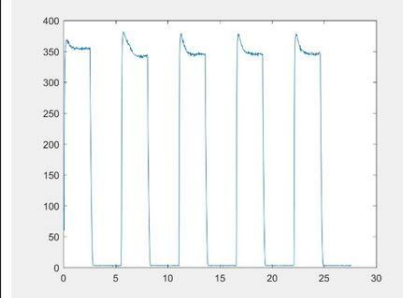
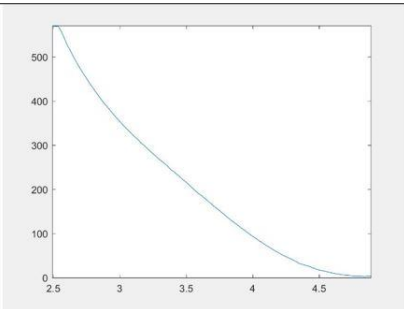
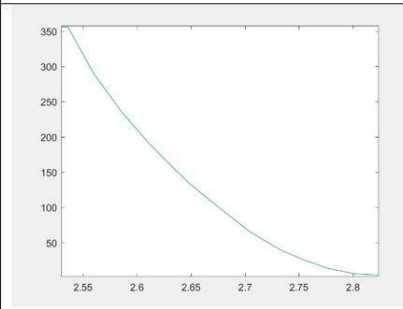
Solidworks allows for holes to be as small as desired, but 3D printers can't make holes be so small and fills them in

Each hole was somewhere between 0.5mm and 2 mm

Here is a graph that shows which were usable, and which holes were filled

Each endcap tested and amount and size of holes	State of hole
2 holes each 1mm thick	One hole was filled
2 holes each 0.5 mm thick	Both holes were filled
1 hole 2mm thick	Hole intersected with the screw hole and the side of the end cap
1 hole 1mm thick	Was not filled and did not intersect anything
1 hole 0.5mm thick	Was filled in when printed

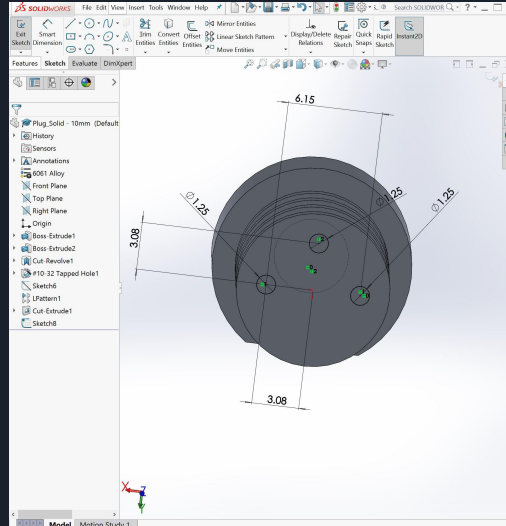
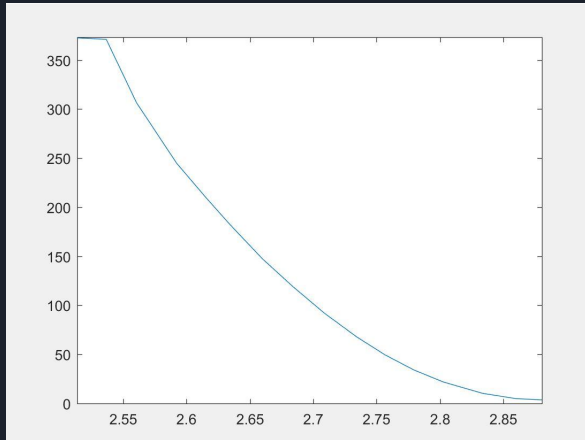
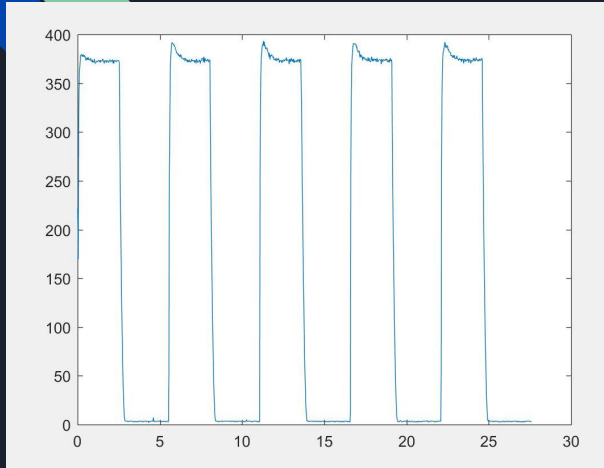
Print test 2 cont.

	1 mm hole end cap	2 mm hole end cap
Full test		
Zoomed in on relaxation		
Time to relax	2000 milliseconds	200 milliseconds

From this print, the 1mm hole and 2mm hole were tested

2mm hole intersected side and screw hole

Print and test 3



Next test: need total hole amount to be greater than 2mm in diameter (bring relaxation time down)

Needed holes to be smaller than 2 mm (not intersect)

Needed holes to be bigger than 1 mm to insure they wouldn't get filled in

Settled on 3 holes each with 1.25 mm diameters

Took 300 milliseconds to relax



Discussion

The closest to 150 milliseconds both had wall problems and jagged graphs

3D printing settings alone are not enough



Further testing

Change both the solid and ported end caps

Add different size holes in different quantities from different places

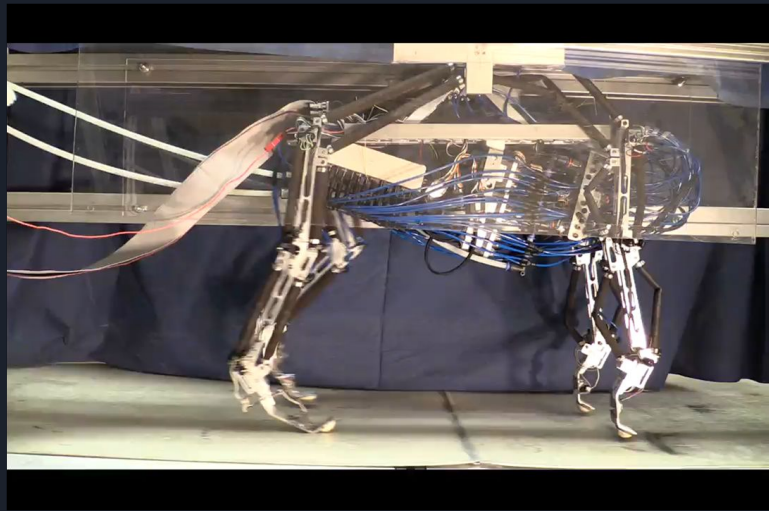
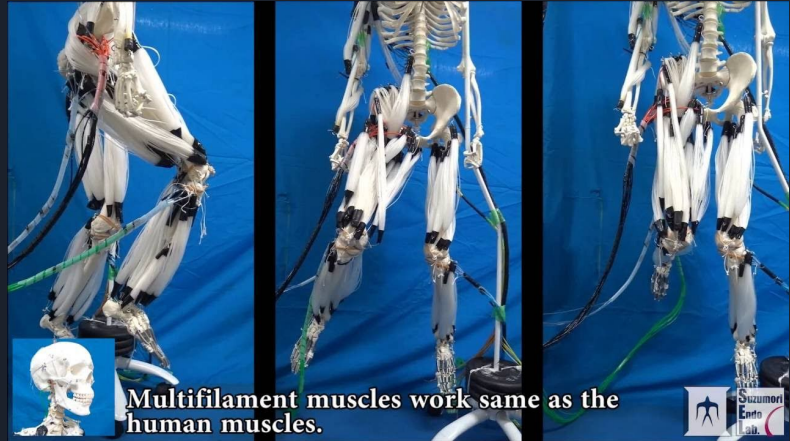
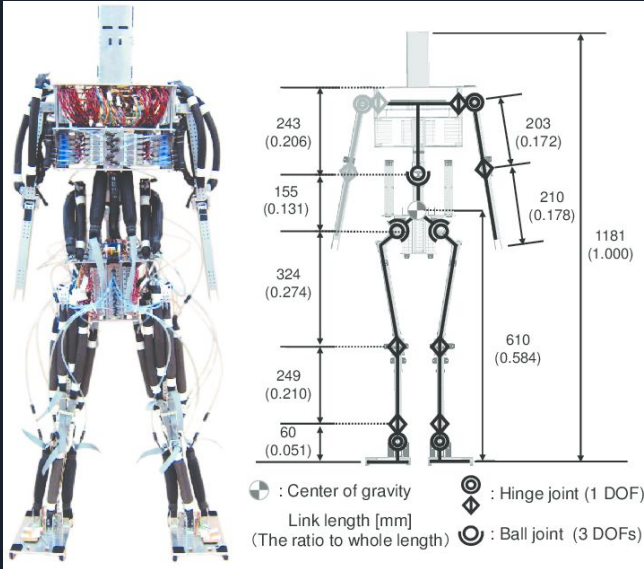
Adjust shape of the end caps

Change 3D printing settings in addition

See if holes get intersected when in use

Store data into arduino board then send back to MatLab;
more accurate and more data points

Where this can go



Acknowledgements

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